CALIFORNIA. DEPT. OF WATER RESOURCES.
BULLETIN.

WATER CONSERVATION

In California

May 1976

save
water
DWR

BULLETIN No. 198
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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State of California
DEPARTMENT OF WATER RESOURCES
P.O. Box 388
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STATE OF CALIFORNIA
The Resources Agency

Department of Water Resources

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WATER CONSERVATION IN CALIFORNIA

MAY 1976

CLAIRE T. DEDRICK
Secretary for Resources
The Resources Agency

EDMUND G. BROWN JR.
Governor
State of California

RONALD B. ROBIE
Director
Department of Water Resources

FOREWORD

Throughout our history the need for commodities of all types has generally been met by developing additional resources. This approach has been followed in providing water supplies for municipal, industrial, and irrigation uses. Water conservation traditionally has been considered to mean storage of surface flows in reservoirs. Now, *conservation* has come to mean increasing the efficiency of water use to delay the day when more surface water storage will be needed. By stretching our already-developed supplies, better water management, including greater protection of in-stream uses, is possible.

Bulletin No. 198 presents approaches to the current meaning of water conservation — methods that will help save water and energy and reduce waste.

This bulletin describes current water use practices and possible methods of water savings and identifies where they might be most effectively used. It reviews water conservation programs already established in some parts of California and the Nation.

This Department of Water Resources bulletin makes specific recommendations for immediate action. In addition we will develop a more detailed statewide water conservation program in the months that follow.

The current dry weather emphasizes the need for water conservation and reminds us that our resources are finite. We need a commitment by both utility managers *and* consumers to implementation of water conservation programs on a long-term basis, not just in times of shortages. Without such a commitment, as supplies return to normal, we will lapse back into wasteful ways.

Ronald B. Robie

Ronald B. Robie, Director
Department of Water Resources
The Resources Agency
State of California

CONVERSION FACTORS

English to Metric System of Measurement

Quantity	English unit	Multiply by	To get metric equivalent
Length	inches (in)	25.4	millimetres (mm)
		.0254	metres (m)
	feet (ft)	.3048	metres (m)
	miles (mi)	1.6093	kilometres (km)
Area	square inches (in^2)	6.4516×10^{-4}	square metres (m^2)
	square feet (ft^2)	.092903	square metres (m^2)
	acres	4046.9	square metres (m^2)
		.40469	hectares (ha)
		.40469	square hectometres (hm^2)
		.0040469	square kilometres (km^2)
	square miles (mi^2)	2.590	square kilometres (km^2)
Volume	gallons (gal)	3.7854	litres (l)
		.0037854	cubic metres (m^3)
	million gallons (10^6 gal)	3785.4	cubic metres (m^3)
	cubic feet (ft^3)	.028317	cubic metres (m^3)
	cubic yards (yd^3)	.76455	cubic metres (m^3)
	acre-feet (ac-ft)	1233.5	cubic metres (m^3)
		.0012335	cubic hectometres (hm^3)
		1.233×10^{-6}	cubic kilometres (km^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
		.028317	cubic metres per second (m^3/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
		6.309×10^{-5}	cubic metres per second (m^3/s)
	million gallons per day (mgd)	.043813	cubic metres per second (m^3/s)
Mass	pounds (lb)	.45359	kilograms (kg)
	tons (short, 2,000 lb)	.90718	tonne (t)
		907.18	kilograms (kg)
Power	horsepower (hp)	0.7460	kilowatts (kW)
Pressure	pounds per square inch (psi)	6894.8	pascal (Pa)
Temperature	Degrees Fahrenheit (°F)	$\frac{tF - 32}{1.8} = tC$	Degrees Celsius (°C)

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WATER MANAGEMENT POLICY OF THE DEPARTMENT OF WATER RESOURCES

Adopted May 7, 1975

It is the policy of the Department of Water Resources that the water resources of California shall be managed in a manner that will result in the greatest long-term benefit to the people of the State.

Water resources already developed shall be used to the maximum extent before new sources are developed.

All alternative sources of supply, including water exchanges, shall be considered. Conjunctive use of surface and ground water supplies and storage capacity, including planned temporary overdrafting of ground water, shall be utilized to maximize yield and improve water quality.

To maximize beneficial use, optimum application techniques and processes for water conservation shall be implemented and waste shall be avoided.

Water shall be reused to the maximum extent feasible.

Instream uses for recreation, fish, wildlife, and related purposes shall be balanced with other uses.

Water quality objectives and beneficial uses adopted by the State Water Resource Control Board shall be the basis for water quality management.

Consideration of methods to prevent property damage or loss of life from floods shall include flood plain zoning, flood proofing, flood warnings, and similar measures as well as construction of facilities such as reservoirs and levees.

In comparing alternative water management possibilities, consideration shall be given to capital and annual costs, cost-effectiveness, economic and social benefits, environmental and ecological effects, and energy requirements. The least expensive alternative will not necessarily be selected.

Water management shall be based upon existing laws, but new legislation may be sought where existing law is inadequate.

FINDINGS AND RECOMMENDATIONS

Water-saving opportunities exist throughout the State. Since conditions vary from place to place, specific opportunities must be identified individually. The greatest potential savings are found in areas where significant quantities of return flow from excess water applications are disposed to saline waters without serving further beneficial use. But even in areas where water conservation measures will not save large quantities of water, they may result in energy savings and offer opportunities for environmental improvement through changes in water management.

The following summarizes the findings of this report, presenting water-conservation methods and potential water-savings opportunities, specific actions the Department of Water Resources (DWR) will undertake, and recommendations for actions by others.

Urban Water Conservation

Statewide, urban water use is 68 percent residential, 14 percent commercial and governmental, and 18 percent industrial. Of the residential, about 56 percent is for interior use; most of the remaining 44 percent is used for landscape watering.

Interior Residential Water Savings

The following table indicates the possible statewide residential interior water use savings that might result from various water conservation actions:

POTENTIAL RESIDENTIAL INTERIOR WATER SAVINGS

Feature	Added Cost Per Unit ($)	Water Savings as a % of Interior Use	Potential Year 2000 Statewide Water Savings (1,000 acre-feet)	(Cubic Hectometres)
New Construction:				
● low-flush toilets	0-10	18	185	230
● low-flow showerheads	0-5	12	125	155
● low-flow kitchen & lavatory faucets	0-5	2	20	25
● pressure reducing valves	0-25	5	50	60
● insulated hot water lines	0.50-1.00 per foot of line (1.65 - 3.00 per metre)	4	40	50
● low-water using clothes washers	20-30	5	50	60
● low-water using dish washers	0	4	40	50
		Sub Total	510	630
Existing Housing:				
● plastic bottles or water dams in toilet reservoir	0-6	18	345	425
● replace showerheads with low-flow variety or install flow restrictors	1-5	12	230	285
● place low-flow aerators on kitchen & lavatory faucets or replace entire unit	1-5	2	40	50
● pressure reducing valves	25	5	95	115
● insulated hot water lines	0.50 or more per foot of line (1.65+ per metre)	1	20	25
		Sub Total	730	900
		Total	1240	1530

DWR recommends that:

1. *in all new construction the following be required, either through state legislation or local building code changes:*
   - *low-flow toilets (state legislation enacted in 1976).*
   - *low-flow faucets*
   - *low-flow showers*
   - *pressure reducing valves where line pressure is above 50 psi*
   - *insulated hot water lines;*
2. *local agencies encourage the following to be installed in existing housing, through education programs and by providing the water-saving devices free or at cost:*
   - *weighted plastic bottles, water dams, or other devices in toilet reservoirs to reduce flush-flows*
   - *low-flow showerheads or flow restrictors in the shower line*
   - *low-flow aerators on faucets*
   - *pressure reducing valves where line pressure is greater than 50 psi;*
3. *only low-water-use clothes and dish washers be sold in the State;*
4. *manufacturers of plumbing fixtures and water-using appliances be required to prominently display water use characteristics;*
5. *local governments adopt ordinances that require phasing out of home self-regenerating water softeners and replacement with centrally regenerated units.*

DWR will:

1. *assist local agencies in formulating necessary building and plumbing code changes to require water-saving devices;*
2. *in cooperation with local agencies, develop and submit specific recommendations to the International Association of Plumbing and Mechanical Officials on modifications to the Uniform Plumbing Code regarding requirements for water conservation considerations in the design of fixtures and in other aspects of plumbing.*

Exterior Urban Water Savings

Reduction in outside water use requires more careful landscape watering, i.e., reducing runoff and percolation of water below the roots. Automated sprinkling systems controlled by soil-moisture sensing devices are very effective, but costly. Education on proper watering techniques, followed by a little care on the part of the homeowner, should be all that is needed to make significant savings in some areas (potential water savings vary greatly from place to place). Planting drought-resistant vegetation would also reduce water needs. The public should be informed of the possibility, and nurseries should be encouraged to promote this kind of landscaping. Estimated potential reduction in year 2000 water requirements for landscape watering is 200,000 acre-feet (250 cubic hectometres) per year.

DWR recommends that:

local agencies conduct vigorous programs to reduce exterior water use through public education on lawn and garden watering and low-water using landscape vegetation; establish and enforce irrigation schedules; and provide penalties for gutter flooding or other waste such as excessive use of water for driveway and automobile washing.

DWR will:

encourage the California Association of Nurserymen and similar professional groups to promote the use of low-water-using landscape vegetation.

Urban Water Pricing

To be effective in reducing water use, the cost of water must be made a significant item in the user's budget or operating expenses, and the user must be made aware of the relationship between quantity used and cost. Flat rates and decreasing block rates, both quite common in California, do not do this. The increasing block rate, the peak or seasonal use rate, and to a lesser extent, the uniform rate can, in some cases, accomplish this. In addition, eliminating ad valorem taxes for water and collecting the revenue through the rate structure, and similarly handling sewage treatment charges would further contribute to the user's awareness of the quantity-cost relationships. Attempts to control water use by water pricing must be carefully conceived, to avoid unnecessary or unwanted impacts on the quality of life, on any one segment of society, or on the utility supplier. All basic needs must be met on an equitable basis and prices increased only for that quantity above the minimum required. The lifeline rate system follows this concept.

DWR recommends that:

water agencies use uniform, peak/seasonal, or increasing block rates in water pricing. Where possible, ad valorem taxes for water should be eliminated and sewage treatment costs included in the same billing system. Where appropriate, the lifeline rate concept should be included in the pricing system.

DWR will:

acquire the necessary expertise to provide technical assistance to local water agencies in their efforts to select effective pricing structures.

Urban Water Leakage

Most California water agencies supplying urban water estimate leakage losses to be eight percent or less. Based on the experience of East Bay Municipal Utility District in its concerted effort to detect and close leaks in a portion of its service area, the potential statewide water savings through vigorous leak detection and repair programs would be about 200,000 acre-feet (250 cubic hectometres) per year.

DWR recommends that:

all water agencies institute effective delivery system leak detection programs .

DWR will:

examine the water systems throughout the State and recommend appropriate measures to ensure that actions are taken.

Although there is no basis from which to estimate the potential quantity involved, repair of household leaks appear to offer opportunities for significant water savings. In addition to water loss, hot water leaks also waste energy. While faucet leaks can be detected visually, identifying leaky toilets often require adding dye to the water in the toilet reservoir.

DWR recommends that:

all water agencies promote and assist in the detection and repair of household plumbing leaks.

Commercial and Governmental Water Savings

The means for reducing residential waste of water are also appropriate for the commercial and governmental sector. Implementation of similar measures by commercial and governmental users might save 150,000 to 300,000 acre-feet (185 to 370 cubic hectometres) of water statewide annually at year 2000.

DWR recommends that:

actions recommended for the residential sector also be undertaken in the commercial and governmental sectors.

DWR will:

work with other state agencies to develop water conservation programs at state facilities.

Industrial Water Savings

In the industrial sector, savings are most possible through recycling of water. This already has received a great amount of attention by some industries in their effort to control waste discharges to avoid penalties for contributing to water pollution. Industry, particularly, has benefited from water-pricing systems which favor large water users. Revisions of these systems would encourage additional efforts to reduce freshwater intake.

DWR recommends that:

water-pricing structures that favor large water users be replaced with uniform or increasing block rate structures.

Agricultural Water Conservation

Depending on the circumstances in each case, agricultural irrigation efficiency may be increased by changing to sprinkler or drip systems, improving operation of existing systems (including better irrigation scheduling) and improving other aspects of farm management. Irrigation water use may be reduced by selecting low-water-using crops, and in some cases, by actions to reduce plant consumptive use. Water districts can save water by lining ditches and canals and assist farmers in becoming more efficient by following more effective water delivery schedules. The opportunity for water savings in an area depends on how much outflow is needed to maintain salt balance and the disposition of the excess applied water, i.e., whether it is reused, or disposed of into bodies of saline surface or ground water. Considering these factors and current technology, the approximate reasonably attainable savings of the *current agricultural supply* are estimated to be as follows:

	Acre-Feet	Cubic Hectometres
Central Valley	650,000	800
Colorado Desert	400,000	500
Remaining Areas	150,000	200
Statewide Total	1,200,000	1,500

To accomplish the 650,000 acre-feet (800 cubic hectometres) of savings in the Central Valley, water storage facilities would have to be available (surface and/or ground water storage) to make the quantity saved available when needed for further beneficial use. This total does not reflect the water deficiencies in Tulare Lake Basin resulting from (1) ground water overdraft, and (2) the need to export more irrigation drainage water from the basin to establish a favorable salt balance.

In order to achieve these savings, the need and methods for water conservation and advantages of increased irrigation efficiency must be made known to farmers. In addition, other motivating actions, such as water-price changes, must be taken.

DWR recommends that:

1. *federal and local water agencies strongly promote water conservation in their agricultural water service areas through public education programs. University of California Cooperative Extension Service should cooperate in this;*
2. *farmers be encouraged to plant low-water-using crop to the extent that market conditions allow;*
3. *U.S. Bureau of Reclamation, Soil Conservation Service, and U.C. Cooperative Extension Service expand irrigation advisory services;*
4. *University of California, State Universities, and others step-up irrigation research and demonstration activities;*
5. *research be expanded on means to reduce crop water use (evapotranspiration), including the use of antitransparent chemicals and the allowable soil-moisture deficiency at various stages of plant growth that will not significantly impact crop yields;*
6. *where there are high water table problems, drainage systems be installed to increase crop production per unit volume of water used;*
7. *ditches and canals be lined to eliminate seepage losses, particularly where the water percolates down into saline ground water or contributes to crop production loss due to high water tables.*

Agricultural Water Pricing

Agricultural water prices vary over a wide range throughout the State. In most areas, water costs are a relatively small part of the total cost of operations, and therefore, are not generally an incentive for frugal use of the water. The ability to pay for water varies greatly depending on the crops and the nature of the farm operations. Generally, small farmers have less flexibility to change water use practices in response to price changes than large farmers. In many areas, the price of water is subsidized through power sales, by increased prices to urban users, and through general taxation.

DWR will:

examine water-pricing policies and recommend changes on a case-by-case basis which will encourage water conservation.

General

The following pertain to all water use.

DWR will:

1. *encourage that all water pricing be based on costs except where public policy dictates otherwise;*
2. *conduct studies to identify specific areas of opportunities for water savings;*
3. *take legal action and encourage the State Water Resources Control Board to take actions to eliminate waste and non-beneficial use of water;*
4. *encourage the State Water Resources Control Board to require water conservation as a condition for approval of new water rights applications;*
5. *work with local agencies statewide to develop education programs to promote water conservation;*
6. *encourage and support research and demonstration of devices and methods for water conservation;*
7. *seek legislation to provide authority to water agencies to require water conservation actions as a condition of new service;*
8. *require water conservation as a condition for approval or support for loans and grants for water-related actions;*
9. *consider opportunities for water conservation in establishing priorities for use of the water supply;*
10. *reorient DWR planning programs to give major emphasis to water conservation;*
11. *in studies of possibilities for improving instream water uses, examine how increased efficiency of water use in the urban and agricultural sector may allow different water delivery system design and operation in order to leave more flows in certain stretches of our streams and rivers.*

CHAPTER I. INTRODUCTION

For many years, California has met the constantly increasing demand for water through the development of new sources of supply. From the drilling of new wells to the recent and complex State Water Project, new sources of water have been developed to sustain the thriving California economy and to maintain the comfort and well being of the growing population.

The future development of surface and ground water resources will certainly remain as important considerations in the California water picture. Today, however, with the increasing concern for preservation of the native values of our rivers, fisheries, and recreation opportunities, the continually increasing cost of water development and the use of energy, the emphasis is moving toward alternative methods to satisfy increasing water demands. These include better integration of surface and ground water supplies, water exchanges, reclamation of waste water, and water conservation — using less water to accomplish the same purpose.

The opportunities for applying new technologies and making other changes in our management of the water resource, must be fully assessed and implemented as soon as possible. As indicated in the statement of water management policy (page x), the Department of Water Resources is dedicated to providing strong leadership in accomplishing these objectives.

This report is concerned with urban and agricultural water conservation. It is intended to provide a foundation of knowledge on available measures for obtaining more efficient use of our water supplies.

Bulletin No. 198 presents a number of water-saving measures, analyzes their effects — favorable and unfavorable — and discusses how such measures might be implemented.

More specifically, Bulletin No. 198:

1. Discusses the legal basis for water conservation.
2. Describes current water use practices.
3. Presents possible methods of water conservation.
4. Assesses the advantages and limitations of the various methods.
5. Identifies, generally, where various methods might be most effectively used.
6. Estimates the potential water savings that could result from use of such methods.
7. Provides some assessment of overall impact on the water supply and quality, environment, and economy, including the estimated costs of implementation.

Chapter II discusses certain aspects of water use which are important to consider in assessing the opportunities for water saving in California.

Chapter III presents the various methods for reducing water use in the urban sector and provides estimates of potential water savings based on projections of year 2000 population.

Chapter IV presents the methods for water conservation in the agricultural sector.

Chapter V contains discussions of current irrigation water use and practices, the hydrologic characteristics that affect opportunities for water saving, and provides estimates of potential savings of current supplies in each of the eleven hydrologic study areas of the State.

Before proceeding further, however, it is important to consider the legal foundation for the Department of Water Resources involvement in programs to promote water conservation.

Legal Basis for Water Conservation

It is the policy of the State of California to put its water resources to beneficial use to the fullest extent of which they are capable. It is also the policy of the State of California to prevent waste or unreasonable use, method of use or method of diversion of its water resources. This policy is embodied in Article XIV, Section 3 of the California Constitution adopted by the people on November 6, 1928.

Article XIV, Section 3, states in part:

> "It is hereby declared that because of the conditions prevailing in this State the general welfare requires that the water resources of the State be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare. The right to water or to the use

or flow of water in or from any natural stream or water course in this State is and shall be limited to such water as shall be reasonably required for the beneficial use to be served, and such right does not and shall not extend to the waste or unreasonable use or unreasonable method of use or unreasonable method of diversion of water."

This policy has also been codified by the Legislature in Section 100 of the Water Code.

The Department of Water Resources is directed by Section 275 of the Water Code to prevent waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water.* This, together with Section 225 and 226, which authorizes the Department to investigate water use and the rate of water use among other things, constitute the basis for this report.

The Department has developed a water management policy which includes its responsibilities under Section 275 of the Water Code. The pertinent excerpts are:

"Water resources already developed shall be used to the maximum extent before new sources are developed.

"To maximize beneficial use, optimum application techniques and processes for water conservation shall be implemented and waste shall be avoided.

"Water shall be reused to the maximum extent feasible."

We consider practical water conservation measures must be implemented to demonstrate water is being used reasonably. Accordingly, this state-of-the-art report will be used to further define practical conservation measures as a means of measuring reasonable use under specific conditions.

Despite the fundamental pronouncements contained in Article XIV, Section 3 and Water Code Section 100, lawsuits which have been brought pursuant to these provisions have, until recently, involved disputes between competing water rights claimants only. These provisions have not been used as a basis for stimulating new methods of water conservation or use. This, however, is changing.

In *Environmental Defense Fund* vs. *East Bay Municipal Utility District,* 52 C.A.3d. 828 (Nov. 1975), the California Court of Appeal ruled that a failure to reclaim and reuse waste water may, upon a proper showing, violate the mandate of Article XIV, Section 3, of the California Constitution**. The plaintiffs, in this case, argued that the District was violating Article XIV, Section 3, by, among other things, not first reclaiming and reusing its waste water to aid in supplying its water requirements before it sought a new source of water. The trial court dismissed the case, ruling that the factual allegations in the complaint, even if true, would not constitute a violation of Article XIV, Section 3. The Court of Appeal disagreed and reversed the verdict. The Court ruled that a failure to reclaim waste water may violate the prohibition against waste and unreasonable use of water contained in Article XIV, Section 3, and that the plaintiffs are therefore entitled to the opportunity to prove their allegations at trial. This, the Court pointed out, would require a demonstration that reclaiming waste water has become an economically practicable and feasible method of preventing waste in connection with the District's operations.

The East Bay Municipal Utility District case is an important decision and demonstrates the California Judiciary's recognition of the "necessity", as the Court of Appeal put it, "for flexibility in construing the law to keep pace with the needs and transformations constantly taking place in our rapidly changing society."† In this context, the "need" is to make the most effective use of our valuable water resources through the application of the latest conservation and reclamation technology.

The Legislature has also recently demonstrated its awareness of the necessity for innovative laws to encourage water conservation and reuse. In 1975, the Legislature enacted Section 71610.5 of the Water Code, which authorizes Municipal Water Districts to initiate water conservation programs and to require as a condition of new service, that reasonable water saving devices and water reclamation devices be installed. Although restricted to new service, this provision does provide power to Muni-

*Section 275, Water Code: "The department and board shall take all appropriate proceedings or actions before executive, legislative, or judicial agencies to prevent waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water in this State."

**Petitions for a hearing before the California Supreme Court have now been filed, although no decision has been rendered on the petitions as of the date of publication of this bulletin.

†52 C.A.3d 844.

cipal Water Districts to take positive steps to incorporate new technology and methods to reduce water use.

In 1976, Section 17921.3 was added to the Health and Safety Code. This new section requires low-flush toilets in hotels, motels, apartment houses, and dwellings constructed after January 1, 1978.

We are hopeful that in the legal arena, this is only the beginning.

CHAPTER II. WATER USE IN CALIFORNIA

The intent of this chapter is to describe some of those aspects of water use in California that are important to consider in evaluating the methods and potential opportunities for water conservation discussed in this report.

The Water Cycle

Water is used and reused in a never-ending hydrologic cycle, consisting of precipitation, evaporation, transpiration, and runoff. Portions of the surface runoff return to the atmosphere by evaporation, recharge ground water basins, or flow to the ocean. In some areas the ground water level rises to the ground surface and evaporates or is transpired by vegetation or supplements surface runoff. Ground water in coastal basins also discharges to the ocean. Evaporation from the ocean and inland water bodies provides moisture for precipitation, and the cycle repeats itself. Essentially, no water is gained or lost; it merely changes form — liquid, solid, or gas.

People are primarily involved in the cycle through the impoundment or diversion of surface water and pumping of ground water, principally for agricultural and urban uses. In our use of water, portions of it evaporate, transpire, or are lost to the ocean or other bodies of salt water. However, significant quantities are returned to surface or ground water systems and are then reused.

The Significance of Reuse

What happens to the water we convey and use? The *applied water demand* for urban, agriculture, recreation, and fish and wildlife purposes is the quantity made available at the point of use — e.g., at the farm headgate, the factory, or the place of intake to a city water system. In addition, the unregulated return flows from urban and agricultural areas that support wildlife habitat and sustain fisheries are part of this total applied water demand.

The amount of primary water supply needed to satisfy all of these uses may be considerably less than the sum of all the quantities applied. This is because some of the excess applied water is reused — in some cases many times. The actual water supply necessary to meet all applied water demands is termed *net water demand,* which is determined by adding all the applied water uses and subtracting all reuse within the service area (or by adding all evapotranspiration of applied water and service area outflow).

Net water demand shown in Figure 1 is the sum of water applied to farms "A" and "B", the wildlife area, and delivered to the City (157 units); minus reuse of surface return flows from farm "A", the wildlife area and the City (45 units), minus the reuse of water that has percolated to ground water from farm "A" and the City (12 units). Net water demand in this case is 100 units. The 10 units of outflow from the service area would be a prime water supply to a downstream user.

A reduction of 10 units of diversion from the river made possible by increased water use efficiency by farm "A" and the City would have the effect of eliminating the 10 units of usable outflow from the service area. Although the service area's net water demand would be reduced to 90 units, there would be no change in the supply to downstream users. Conservation measures could save 10 units of water only if there were no downstream reuse.

A reduction of 15 units of diversion from the river, again due to increased efficiency by farm "A" and the City, would result in a water supply deficiency at farm "B", i.e., 5 units less supply than evapotranspiration requirements. An additional 5 units would have to be diverted from the river to meet farm "B"'s full evapotranspiration requirements. With this, the net water demand would again be 90 units.

Although the foregoing is a greatly simplified example, it does describe a situation that is typical of most hydrologic study areas of the State. In most areas, however, there are additional factors to consider in evaluating the effect of water conservation. Within some water service areas, a portion of the return flow moves into saline drains or percolates to saline or poor-quality ground water basins, which eliminates or greatly reduces the opportunity for reuse. In some situations, the surface outflow from a service area empties into the ocean or highly saline lakes. In these cases, increased water use efficiency would save water, i.e., it would decrease net water demand.

Increased efficiency might be desirable even though it might not save significant amounts of water. For example, water passing through the soil mantle picks up soluble salts that are carried into the ground water. Increasing applied water use efficiency may be very important in order to protect the quality of the ground water supply.

In some areas, particularly Northern California, changing the points of diversion of primary water supplies or the routing of return flows may allow increased environmental amenities, such as increased nonconsumptive fish flows in certain river stretches, while still allowing for all of the consumptive uses.

Finally, regardless of the amount of water that can be saved, increased water use efficiency could be very important from the standpoint of overall energy savings; that is, less water might be pumped from underground or from drains.

Current Water Use

Figure 2 presents the percentage distribution of statewide water demands by type of use. The value for fish, wildlife, and recreation represents only that quantity of water used in fish and wildlife

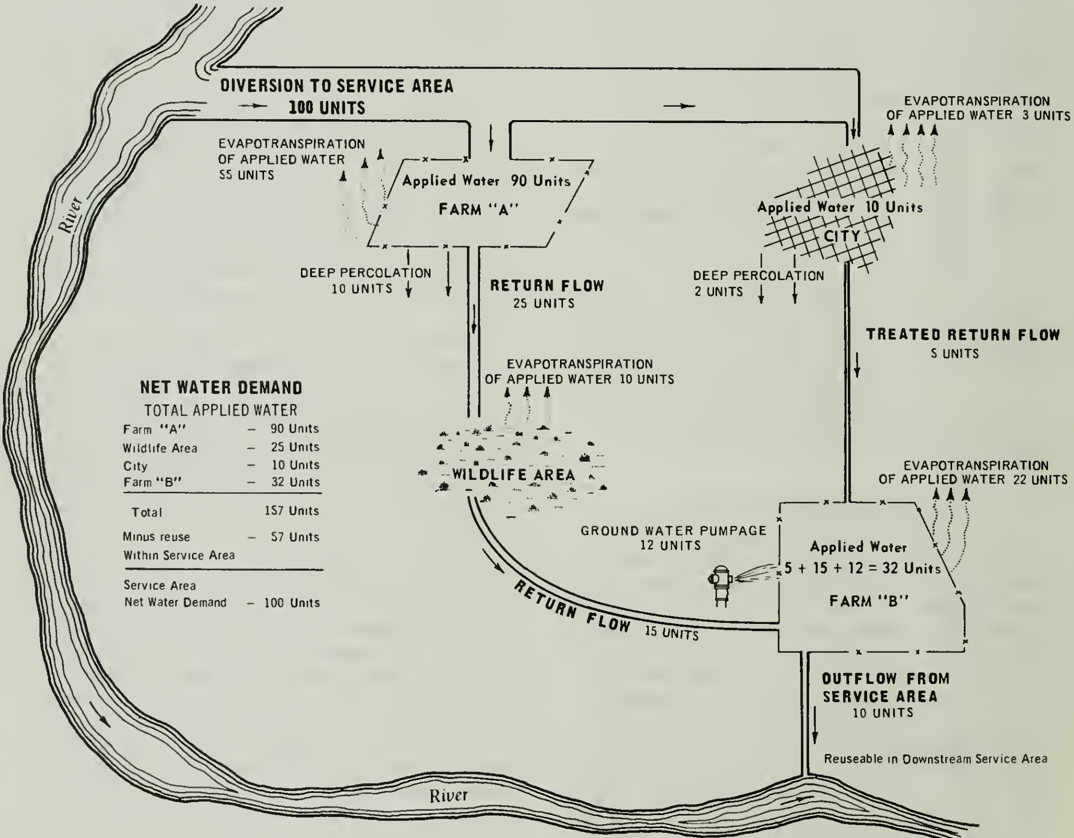
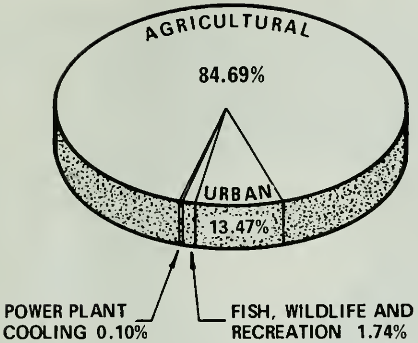


Figure 1. Derivation of Net Water Demand



	1,000 ac-ft	cubic hectometres
URBAN	5,040	6,220
AGRICULTURAL	31,700	39,100
POWER PLANT COOLING	40	50
FISH, WILDLIFE AND RECREATION	640	790
STATE TOTAL	37,420	46,160

Figure 2. Statewide Water Demand by Type of Use, 1972

management areas and the out-of-stream use by recreationists in park areas removed from urban centers.

Figure 3 presents the total applied water demands in each of the 11 hydrologic study areas of the State.

Figure 4 compares applied water demand with net water demand in each hydrologic study area. The net water demand for each area was derived as explained in the preceding section ("The Significance of Reuse"). The difference between total applied water demand and net demand in coastal areas is quite small. This is due to the limited amount of reuse within these areas, i.e., large amounts of once-through water flow from large metropolitan areas directly into the ocean. In addition, a large portion of percolating return flow from agricultural areas also gravitates directly to the ocean, although in some basins this migration establishes a freshwater barrier that protects the ground water basin from salt water intrusion. Increased applied water use efficiency in these coastal areas could markedly decrease net water demand.

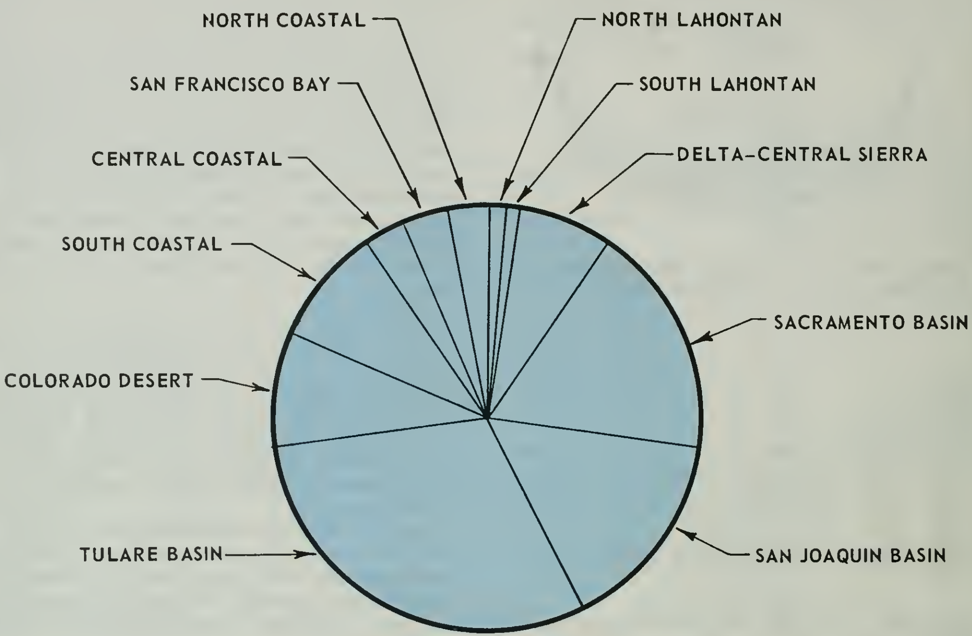
In contrast to the coastal areas, net water demands are considerably lower than applied water demands in the Central Valley hydrologic study areas due to the large opportunity for reuse. Part of the net water demand for the Sacramento Basin, Delta-Central Sierra, and San Joaquin hydrologic study areas is outflow which enters the Delta, where it becomes part of the prime supply to that area. In the Central Valley, water conservation practices must be evaluated not only in terms of their local effect but also in terms of their effect on the Delta; that is, reduction in return flow may have to be made up by increased reservoir releases. In this case the net water demand would remain the same.

In the Colorado Desert hydrologic study area, net water demands exceed total applied water demands because of the relatively large loss of canal seepage and tailwater to saline surface and ground waters. Increased irrigation efficiency and canal lining would save significant quantities of water here. However, the reduced seepage and tailwater losses would probably result in a negative impact on the Salton Sea.

The feasibility of implementing water conservation practices must be carefully evaluated with full knowledge of their effect on our surface and ground water supplies, water quality, energy consumption, streamflow, public health, fish, wildlife and recreation.

Energy Consideration

Large amounts of energy are used to operate pumps to move water from place to place, for extraction of ground water, and to pressurize distribution systems. Increases in water use efficiency can have significant impact on energy use. In addition to reducing the amount of water that must be imported from distant points (and the large amount of energy needed for pumping, as in the case of the South Coastal area) and the amount of ground water needed to be pumped in areas where this is the principal supply, increased efficiency would allow expanding the use of developed surface water supplies into areas currently served by ground water. Also, any reductions in the volume of sewage flows would reduce energy requirements for waste treatment. However, some trade-offs must be examined on a case-by-case basis. For instance, conversion to sprinkler systems is a major method for increasing irrigation efficiency. The energy required to pressurize these systems must be considered in determining net change in energy use.



TOTAL APPLIED WATER DEMAND – 1972

	1,000 ac-ft.	cubic hectometres	%
North Coastal	1,120	1,380	3.0
San Francisco Bay	1,260	1,560	3.4
Central Coastal	1,210	1,490	3.2
South Coastal	3,320	4,100	8.9
Sacramento Basin	6,610	8,150	17.7
Delta – Central Sierra	2,670	3,290	7.1
San Joaquin Basin	5,730	7,070	15.3
Tulare Basin	11,300	13,940	30.2
North Lahontan	460	570	1.2
South Lahontan	400	490	1.1
Colorado Desert	3,340	4,120	8.9
STATE TOTAL	37,420	46,160	100

Figure 3. 1972 Statewide Total Applied Water Demand

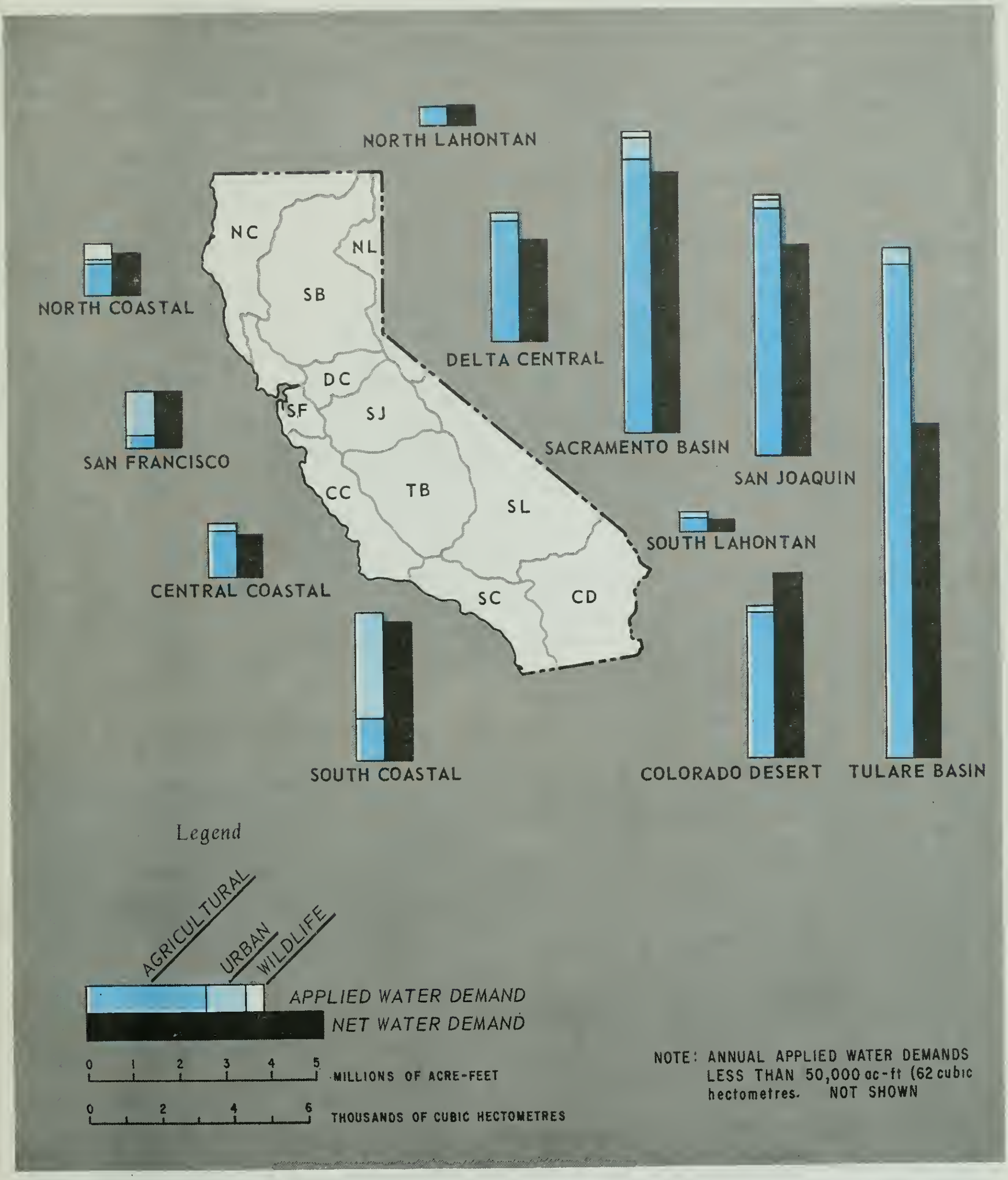


Figure 4. Comparison of Net and Applied Water Demands by Hydrologic Study Area, 1972

CHAPTER III. URBAN WATER SAVINGS

As shown in Figure 5, urban water uses include residential, industrial, commercial, and governmental. Figure 6 shows the quantities of water devoted to urban water uses in each hydrologic study area.

Residential water uses include homes and apartments, while commercial users of water include office buildings, hotels, restaurants, car washes, laundries, golf courses, cemeteries, shopping centers, and retail businesses. Industrial water uses primarily include water for cooling and for manufacturing and processing. Governmental uses include schools, prisons, public hospitals, civic buildings, public parks, etc.

Urban water use comprised about 13 percent of statewide total use in 1972 and is expected to show the greatest proportional increase in the future. Recent projections* indicate that the 1972 urban use of some 5 million acre-feet (6,000 cubic hectometres) might increase to 7.8 million acre-feet (9,500 cubic hectometres) by 2000.

The rate of urban water use is highly variable. Table 1 shows that weighted average per capita water use varies from 179 gallons (678 litres) per capita per day in both the South Coastal and San Francisco Bay HSA's to 521 gallons (1,970 litres) per capita per day in the North Coastal HSA. The latter includes water used by the pulp and paper industry.

In hot, dry areas, such as the San Joaquin Valley and the Colorado Desert, high vegetative water demand increases per capita water use, whereas the higher humidity and moderate temperatures of the coastal areas (San Francisco Bay, Central Coastal, and South Coastal) decrease outside water demand and reduce per capita water use (Table 1).

Climatic influence is also reflected in the seasonal variability of urban water demand. Average daily water use is highest from June through September, while precipitation, lower evapotranspiration rates, and winter dormancy of many plant species reduce outside water use and thereby greatly reduce urban per capita water use during the remainder of the year.

Affluent consumers use more outside water, for irrigation and swimming pools, and somewhat more for water-using appliances such as garbage disposals and automatic dish and clothes washers, than do the less affluent.

Community development and type of water use also affect the rate of use. Per capita water use can be significantly increased beyond normal residential uses by industries in the community. Per capita water use in apartments, townhouses, and condominiums is generally significantly lower than the rate of use in single-family residences, because of lower per capita exterior use.

Understandably, the selling price of water has a significant effect on the rate of water use, although price versus use relationships vary widely from area to area. According to various studies metering also significantly affects residential water use. Water use in certain metered areas is at least 25 percent lower than in areas without meters.

In general, larger families use more water per dwelling but less water per capita. Inside use increases with size of family, but family size affects outside use only slightly.

Finally, water use in sewered communities is higher than in areas where septic tanks are used. This is probably due to the users' concern that septic tanks require frequent cleaning.

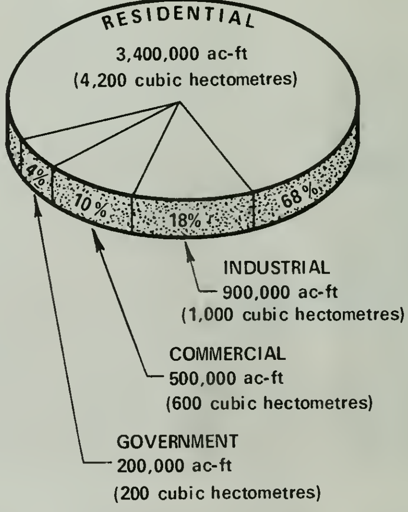
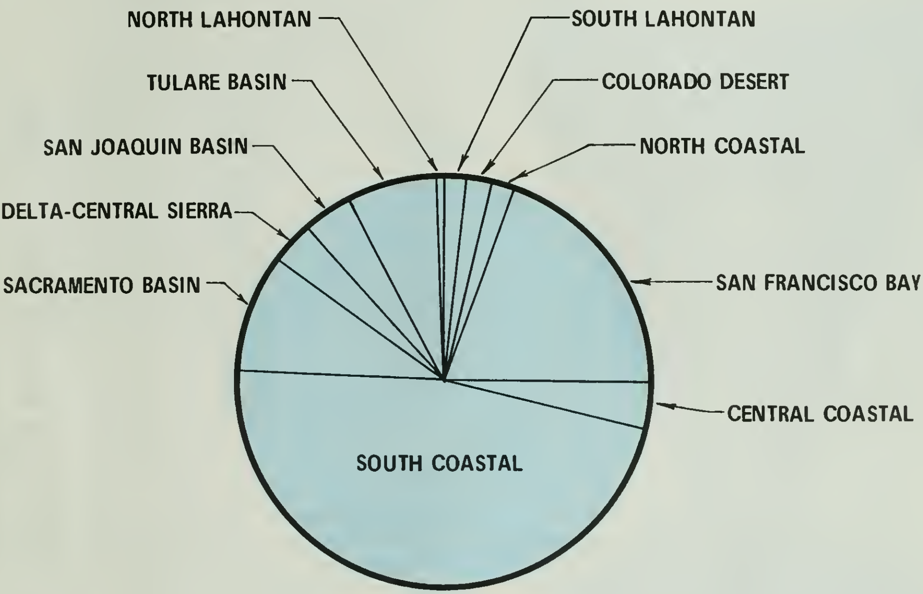


Figure 5. Urban Water Use, 1972

*See DWR Bulletin No. 160-74, "The California Water Plan" — Outlook in 1974". The Alternative III water demand projections contained in that report, which were based on population projection Series D-100, are used as a basis for estimating the potential water savings for year 2000 presented in this chapter.



URBAN WATER USE – 1972

	1,000 ac-ft	cubic hectometres	%
NORTH COASTAL	93	110	1.8
SAN FRANCISCO BAY	990	1,220	19.6
CENTRAL COASTAL	181	223	3.6
SOUTH COASTAL	2,370	2,920	47.0
SACRAMENTO BASIN	470	580	9.3
DELTA-CENTRAL SIERRA	173	213	3.4
SAN JOAQUIN BASIN	192	237	3.8
TULARE BASIN	363	448	7.2
NORTH LAHONTAN	23	28	0.5
SOUTH LAHONTAN	89	110	1.8
COLORADO DESERT	99	120	2.0
STATE TOTAL	5,040	6,210	100.0

Figure 6. Urban Water Use by Hydrologic Study Area, 1972

TABLE 1. AVERAGE ANNUAL URBAN UNIT WATER USE FROM ALL SOURCES BY HYDROLOGIC STUDY AREAS

1966 through 1970

Hydrologic Study Area	TOTAL Agency and Private Industry-Produced Water			
	Gallons per capita daily	Litres per capita daily	Acre-feet per capita annually	Cubic metres per capita annually
North Coastal	521	1,970	0.584	720
San Francisco Bay	179	678	0.200	247
Central Coastal	194	734	0.217	268
South Coastal	179	678	0.200	247
Sacramento Basin	351	1,300	0.393	485
Delta-Central Sierra	315	1,190	0.353	435
San Joaquin Basin	436	1,650	0.488	602
Tulare Basin	363	1,370	0.407	502
North Lahontan	492*	1,860	0.551	680
South Lahontan	305	1,150	0.342	422
Colorado Desert	378	1,430	0.423	522

*Includes tourist use.

Residential Interior Water Savings

Total residential water use in California during 1972 was about 3.4 million acre-feet (4,200 cubic hectometres); of this 1.9 million acre-feet (0,000 cubic hectometres) was for interior use.

Figure 7 shows that 74 percent, or 1.4 million acre-feet (1,700 cubic hectometres), is used in the bathroom; 22 percent, or 420,000 acre-feet (520 cubic hectometres) is used for washing dishes and laundry; and only 4 percent, or 80,000 acre-feet (100 cubic hectometres) is used for cooking. Accordingly, the greatest potential for interior residential water savings will result from lower water use in the bathroom and from reduced water use for dish and clothes washing.

Plumbing Fixtures and Water-Using Appliances

Substantial water conservation can be realized in new homes, or in replacement construction, by the installation of low-flow or water-saving devices. In existing homes, similar savings are possible through retrofitting, i.e., the modification of existing fixtures. Potential savings from various plumbing fixtures and appliances are summarized in Table 2 and discussed briefly in the following paragraphs.

Toilets. Conventional toilets use from 5 to 7 gallons (20 to 30 litres) to remove material from the bowl, wash down the sides of the bowl, and provide a 3-inch-deep water seal in the trap to prevent sewer gas from entering the bowl. Most conventional toilets use more water than is needed to perform the three essential functions.

To remove wastes effectively, a siphon action must be started in the bowl and trap. To achieve this, the water entering the bowl from the tank must have sufficient velocity and volume. However, most toilet tanks have excess volume, and the flush volume can be reduced or controlled by placing plastic bottles or "water dams" in the tank, or by other modifications. Bottles and water dams maintain the static head and the velocity of the water, while reducing the volume. Other devices enable the user to regulate the volume of each flush.

In a number of field tests, conventional toilets were fitted with volume-reducing or flush-control devices: the results showed reductions in water use of up to 25 percent. However, because not all toilets can be retrofitted and most devices tested saved less than 25 percent, 10-18 percent is judged a reasonable range of expected savings.

After the Federal General Services Administration established a water conservation standard of 3.5 gallons (13 litres) per flush for tank toilets, manufacturers designed and marketed toilets to meet the standard. Many toilets available today successfully use 3.5 gallons (13 litres) or less per flush through modified bowl and trap designs and lower volume tanks. Limited field testing of these toilets by the Washington Suburban Sanitary Commission of Hyattsville, Maryland (WSSC) and others showed an 18 percent overall reduction in water use.[1,2]* This reduction was used as a basis for projected savings in this report. Additional testing is being carried out by the U.S. Navy at Camp Pendleton Marine Base; the Department of Water Resources is monitoring these tests.

There is some concern that modifying conventional toilets for a lower volume flush will not completely remove wastes and thus result in additional flushings, or that the reduced volume of water will not carry the wastes to the sewer sublaterals and thus cause stoppages. Computations show that, theoretically, a flush of about 2 gallons (8 litres) will satisfactorily carry waste from the toilet, through collection lines, sublaterals, laterals, and sewers. The computations are based on the slope of collection line specified in the Uniform Plumbing Code ¼ inch per foot (6.4 millimetres per 100 millimetres). If variances from the recommended slope are permitted, the probability of stoppages is increased.

The International Association of Plumbing and Mechanical Officials (IAPMO) publishes and maintains a list (Research Recommendations) of approved plumbing fixtures for new installation; all of these figures meet the standards contained in The Uniform Plumbing Code (UPC). All water saving toilets on IAPMO's list have been tested and will perform satisfactorily.

Whereas retrofit devices may not operate satisfactorily in all conventional toilets, most will operate with a lower volume of water. At present, a number of retrofit devices are available but objective evaluation has been limited. In California, assuming statewide retrofitting and use of low-flush toilets in new and replacement construction, up to 531,000 acre-feet (655 cubic hectometres) less urban water would be required in 2000 (than if current practices are continued).

Shower Heads and Faucets. The ordinary faucet and shower head deliver more water than is actually needed. The flow could be controlled by use of a low-flow fixture, an attachment to the existing fixture, or a flow restrictor in the water line. Flow restrictors that compensate for varying line pressures to deliver a steady flow are now available.

A question still to be answered is, "what are minimum acceptable flows?" The answer depends in part on the appearance of the flow from the

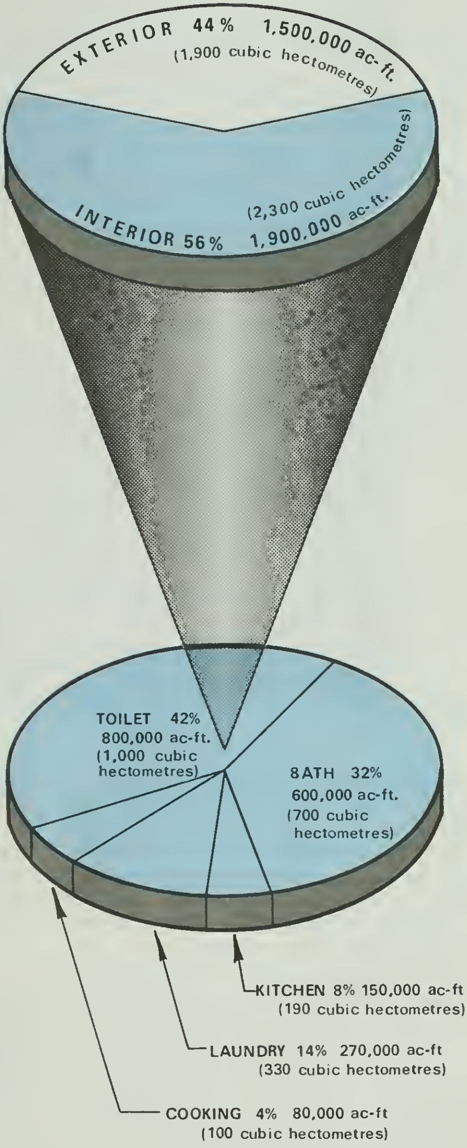


Figure 7 Residential Water Use in California, 1972

*A numbered list of references is presented in Appendix B.

faucet or shower head. The flows cited in Table 2 have had general consumer acceptance in conducted surveys but are not necessarily minimum flows. Some commercial buildings have satisfactorily used 0.5-gallon (2-litre) per-minute lavatory spray taps for years. A spray tap operates like an aerator to break up a small-diameter solid stream of water into a larger diameter spray flow.

Tests conducted by WSCC indicate that the use of low-flow shower heads would result in a water savings of 9 to 12 percent.[2] No similar data on low-flow faucets are available. However, in California, with a complete theoretical changeover to 3.0-gallon (11-litre) per-minute shower heads and 1.5-gallon (5.7-litre) per-minute faucets, up to 413,000 acre-feet (509 cubic hectometres) of water could be saved statewide in 2000.

Automatic Clothes Washers and Dishwashers. For the same load, some clothes washers use 70 percent less water than others; some dishwashers use 50 percent less water than others. In terms of unit water savings, this amounts to reductions of up to 37 gallons (140 litres) for clothes washers[3] and up to 8 gallons (30 litres) for dishwashers.[4] Manufacturers should be required to prominently display the water use characteristics of their machines.

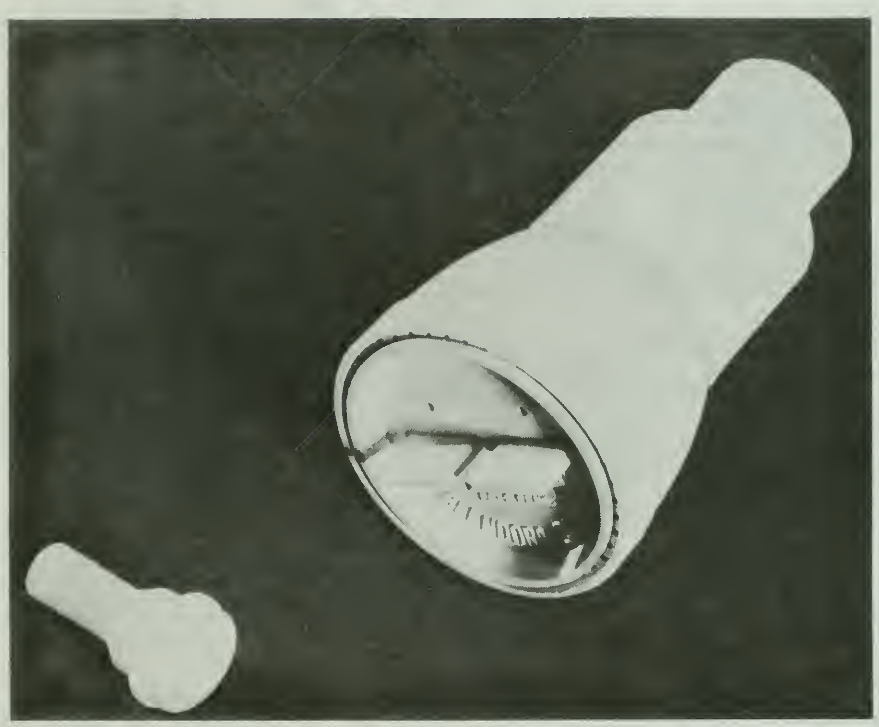
Retrofitting of older wash machines and dishwashers is not considered practical. Therefore, as older appliances are phased out, they should be replaced with models designed to use less water. Water savings with existing appliances can best be effected by educating users to use them less often; e.g., wash full loads. Reduced use of these appliances would also conserve energy.

Pressure Reducing Valves. Water is also wasted by excessive pressure, often exceeding the UPC recommended maximum of 80 pounds per square

TABLE 2. POTENTIAL WATER SAVINGS FROM RESIDENTIAL INTERIOR FIXTURES

Fixture/Action	Water Use		Percent Savings Total Interior		Incremental Cost		In-House
	Standard	Improved	New	Retro	New $	Retro $	Energy Savings
Tank toilet	5-7 gallons (19 to 26 litres) per flush	3.5 gallons (13 litres) per flush	10-18	10-18	$0-$10	$0-$6	No
Shower	up to 12 gallons (45 litres) per minute	3.0 gallons (11 litres) per minute	9-12	9-12	$0-$5	$1-$5	Yes
Kitchen and lavatory faucets	up to 5 gallons (20 litres) per minute	1.5 gallons (5.7 litres) per minute[1]	0-2[2]	0-2[2]	$0-$5	$1-$5	Yes
Pressure reducing valve	80 pounds per square inch (550 kilopascals)	50 pounds per square inch (340 kilopascals)	0-10	0-10	$0-$25	$25	Yes
Hot water pipe insulation[6]	Not insulated	Insulated	1-4[2]	0-1[2]	$0.50-$1.00 per foot	$0.50 per foot	Yes
Automatic clothes washer[7]	27-54 gallons (100-200 litres) per load	16-19 gallons (61-72 litres) per load	0-5	–	$20-$30	Not practical	Yes
Automatic dishwasher[7]	7.5-16 gallons (28-61 litres) per load	7.5 gallons (28 litres) per load	0-4[4]	–	0	Not practical	Yes
TOTAL			20-55[5]	19-43[5]			

1. Attachments marketed with 0.5 gallon (2 litre) per minute flow. Residential acceptance unknown but commercially proven.
2. No field quantification.
3. Retrofitting may not always be practical.
4. Based on one load per day.
5. Educate to only wash full loads, turn off water faucets unless actually used, etc., could add another percent or two to the totals.
6. Insulation of certain continuously circulating hot water piping is already required.
7. 59% of the households in Los Angeles area have washing machines and 24% have dishwashers.



Flow restrictor and low-flow shower head

inch (550 kilopascals), in interior and exterior water lines. In actual practice, a maximum line pressure of 50 pounds per square inch (340 kilopascals) will enable simultaneous effective operation of several appliances. To maintain maximum 50 psi pressures, pressure-reducing valves could be installed in individual households, or a single valve could be used to serve a group of houses.

The unit water savings using pressure reducing valves ranges from 0 to 10 percent for both new and retrofit devices (Table 2).[2] Pressure reducing valves will operate most effectively when flow controls have been installed and when the plumbing system is free from leaks. Older homes with galvanized pipe may require the existing high pressure to deliver sufficient water, because the effective diameter of the pipes has been reduced by corrosion. Assuming 5 percent as the reasonably attainable unit savings, total statewide savings could reach almost 148,000 acre-feet (183 cubic hectometres) per year by 2000.

Insulation of Hot Water Pipes. In most homes, when the hot water faucet is opened, water is wasted while the householder awaits the flow of hot water at the tap. Insulating hot water pipes would decrease the waiting time, thus reducing interior water use by 1 to 4 percent, and save heating energy (Table 2). The State Housing Code now requires that " . . .all continuously circulating domestic . . . hot water piping which is located in attics, garages, crawl spaces or unheated spaces other than between floors or in interior walls shall be insulated to provide a maximum heat loss of 50 BTU/per hour per linear foot (0.3 metre) for piping up to and including 2 inches (50 millimetres), and 100 BTU/per hour per linear foot (0.3 metre) for larger sizes." This same standard could be adopted to include all new construction and should be used as a guide for retrofitting. Hot water heaters can also be centrally located to reduce the distance from heater to the tap.

Costs to Consumers

Purchase of the appliances and devices discussed in the preceding paragraphs would not result in excessive costs to consumers (Table 2). For example, a low-flush toilet may cost about $10 more than a conventional toilet, but increased production should make prices competitive. Low-flow faucets and shower heads cost about $5 more than conventional fixtures; a flow restrictor for the water line costs less than $1.

The cost of retrofit devices for toilets, faucets, and shower heads varies from $1 to $5, depending on the modification. Pressure reducing valves are more expensive, at about $25 per installation. Insulation of hot water pipes will cost an estimated 50 cents to one dollar per lineal foot.

Low-flow toilets and showers, new or retrofitted, are the most cost effective, i.e., least costly per acre-foot of water saved. Prorating the cost over a ten year period indicates that the cost per acre-foot of water saved would be less than $20 per acre-foot. For faucets, pressure reducing valves, and insulated hot water lines, it would range up to a maximum of $150, $150, and $300 per acre-foot, respectively. In some cases, savings in energy cost would offset the cost of these actions. For

TABLE 3. POTENTIAL RESIDENTIAL INTERIOR SAVINGS FOR VARIOUS FIXTURES AND APPLIANCES

Fixture or Appliance	Range of savings, percent	Three coastal HSA's* interior water use		Three coastal HSA's* potential annual savings		Statewide interior water use		Potential statewide savings	
		1,000 acre-feet	cubic hectometres	1,000 acre-feet	cubic hectometres	1,000 acre-feet	cubic hectometres	1,000 acre-feet	cubic hectometres
NEW		Increase, 1972-2000**				Increase, 1972-2000**			
Toilet	18	673	830	121	149	1,036	1,278	186	229
Shower	9-12	673	830	61-81	74-100	1,036	1,278	93-124	115-153
Kitchen and lavatory faucets	2	673	830	13	16	1,036	1,278	21	26
Pressure reducing valves	0-10	673	830	0-67	0-83	1,036	1,278	0-104	0-126
Insulated hot-water pipes	1-4	673	830	7-27	9-33	1,036	1,278	10-41	12-51
Automatic clothes washer	0-5	673	830	0-34	0-42	1,036	1,278	0-52	0-64
Automatic dish-washer	0-4	673	830	0-27	0-33	1,036	1,278	0-41	0-51
Subtotals	10-55			202-370	248-456			310-569	382-700
RETROFITTING		1972 demand				1972 demand			
Toilet	10-18	1,349	1,664	135-243	167-300	1,919	2,367	192-345	237-426
Shower	9-12	1,349	1,664	121-162	149-200	1,919	2,367	173-230	213-284
Kitchen and lavatory faucets	0-2	1,349	1,664	0-27	0-33	1,919	2,367	0-38	0-47
Pressure reducing valves	0-10	1,349	1,664	0-135	0-167	1,919	2,367	0-192	0-237
Insulated hot-water pipes	0-1	1,349	1,664	0-14	0-17	1,919	2,367	0-19	0-24
Subtotals	19-43			256-581	316-717			365-824	450-1,018
TOTAL				458-951	564-1,173			675-1,393	832-1,718

*Central Coastal, San Francisco Bay, and South Coastal

**Projected increase without water conservation; based on D-100 population projections in Bulletin No. 160-74, "The California Water Plan — Outlook in 1974".

TABLE 4. POTENTIAL ANNUAL RESIDENTIAL INTERIOR WATER AND ENERGY SAVINGS, 1972-2000

Item	Type	Three Coastal HSA's[1]		Statewide	
		1,000 acre-feet	cubic hectometres	1,000 acre-feet	cubic hectometres
Water	New[2]	202 to 370	249 to 456	310 to 569	382 to 702
	Retro	255 to 621	315 to 766	365 to 882	450 to 1,088
	Total	457 to 991	564 to 1,222	675 to 1,451	832 to 1,790
		Millions of Barrels of oil[3]			
Energy	New	2.1 to 2.8		3.3 to 4.4	
	Retro	3.2 to 4.3		4.5 to 6.0	
	Total	5.3 to 7.1		7.8 to 10.4	
		Millions of Dollars			
Value of[4] energy	New	24 to 32		38 to 51	
	Retro	37 to 49		52 to 69	
	Total	61 to 81		90 to 120	

1. Central Coastal, San Francisco Bay, and South Coastal Hydrologic Study Areas.
2. New construction savings based on Series D-100 population projections (Bulletin No. 160-74, "The California Water Plan – Outlook in 1974"; Department of Water Resources; November 1974).
3. One barrel of oil will generate about 600 kilowatt hours of electrical energy.
4. Value of energy based on cost of $11.50 per barrel of fuel oil, the recent actual cost for the City of Los Angeles

example, insulating the hot water lines might reduce energy cost by as much as $400 per acre-foot of water saved.

Potential Savings of Water and Energy

Tables 3 and 4 present estimated annual savings of water and energy — in the three coastal areas of California and on a statewide basis — that would result from reduced interior water use. These three areas (the South Coastal, San Francisco Bay, and Central Coastal HSAs) are presented as a single category because together they present the greatest potential savings, considering the large quantities of water used only once and then discharged to the ocean.

On the basis of 1975 costs, in a home equipped with water-saving appliances and fixtures, one might expect a savings in water costs ranging from $11 to $18 per year and a savings in energy costs of $8 to $11 per year. These savings, however, might be only temporary, because as water conservation becomes more widespread and less water is delivered, water purveyors may be compelled to increase unit costs.* In areas where sewer service charges are computed on the basis of water used, one might expect to save an additional $6 to $12 per year. However, most sewer service charges are on a flat-rate basis.

*See "Economics", page 40.

Research, Testing, Data Gathering, and Coordination

1. Conventionally designed fixtures such as toilets and shower heads do not warrant extensive research because only marginal improvements can be expected. However, additional research is needed on:
   a. the design of new plumbing fixtures and water-using appliances.
   b. user habits and preferences to establish minimum acceptable flows of residential water that would produce significant water savings.

Where possible, testing and research should be conducted under actual conditions, i.e., in households.

2. Comprehensive data on acceptable water-saving devices for new homes, and particularly for retrofitting, are needed, so that consumers can be informed of the value of such devices. Although various agencies test new plumbing fixtures (pri-

marily for conformance to codes), no agency tests retrofit devices on a regular basis. Retrofitting of existing plumbing devices would save as much water as would new devices and fixtures installed in homes expected to be constructed between now and 2000.

3. The impact of various types of water-saving devices and appliances must be accurately assessed.

4. Manufacturers should be required to reveal the rates of water and energy consumption of water-using appliances, such as washing machines and dishwashers.

5. The use of appliances and fixtures that require large water flows should be discouraged and perhaps even prohibited. An example is the hydraulically vented toilet, which uses a large water flow to rid the bowl of odors.

6. The Uniform Plumbing Code, in general use in California, is written by the International Association of Plumbing and Mechanical Officials (IAPMO). IAPMO should be encouraged to modify the Code to effect water conservation measures in keeping with public health and safety.

7. When government loans, grants, or mortgage insurance are used for public or private housing, urban renewal, or redevelopment, the installation of water-saving devices should be one of the criteria used to evaluate the proposed loan, grant, etc.

Methods of Implementation

Although some voluntary installation of water-saving devices may result from public education, some means of compulsory installation may be necessary. This might be accomplished by water-utility action, state legislation, or changes in the Uniform Plumbing Code.

At present, the authority of local water agencies to regulate water use is not clear. Under certain conditions, e.g., a water shortage, a local water district could pass an ordinance requiring installation of any or all of the water saving devices described in this report. Water utilities could also require water-saving devices in agreements to provide new service.

A recent addition to the State Water Code, Section 71610.5, authorizes municipal water districts to require, as a condition of new service, that reasonable water-saving devices and water-reclamation devices be installed. Similar pending legislation would extend this authority to all suppliers of water for municipal use, including both existing and new services.

The State Water Code, or the Health and Safety Code, could be amended to include water conservation features applicable to both new and replacement construction. For example, in 1976, Section 17921.3 was added to the Health and Safety Code, prohibiting construction of new hotels, motels, apartment houses, or dwellings which do not employ low-flush toilets of types approved by the State Department of Housing and Community Development. This becomes effective on January 1, 1978. Some minor exceptions are permitted.

The Uniform Plumbing Code could be amended to include water conservation features. This would require action by IAPMO, which meets triennially to review and act on proposed changes. Agencies or organizations proposing changes should establish liaison with IAPMO so that such changes and amendments can receive appropriate consideration.

Residential Exterior Water Savings

About 44 percent of California's residential water is used outside the home, principally for lawn and garden irrigation. For several reasons, however, the reduction of exterior water use has not received the same research and attention as has reduced interior use:

a. In much of the United States, a reduction in interior use has been prompted primarily to reduce waste flows to treatment plants rather than to conserve water.

b. In many parts of the country, exterior water use is seasonal, and far less exterior water is used than in California, where lawns and gardens may be irrigated the year around.

c. The variety of exterior fixtures is limited, as compared to the various types of interior fixtures and appliances, which limits the opportunity for research and innovations.

Some 90 percent of exterior water use is for irrigating lawns, shrubs, and home vegetable gardens; the remaining 10 percent is used for car washing, swimming pools, and cleaning driveways, sidewalks, and streets. Following application, water is stored in plants, transpired, and evaporated. Some runs off into storm drains, or percolates to ground water. Part of the percolated water may infiltrate sanitary sewer lines and be carried to wastewater treatment plants.

Because of this large residential water use for irrigation, significant amounts of water can be saved by eliminating overwatering and reducing evapotranspiration.

Overwatering

Some of the water applied to plants and shrubs evaporates and some is used for growth (transpiration). Water in excess of these quantities either runs off or percolates. Although water deficiency will hinder plant growth and productivity, plants that need only moderate or small amounts of water are usually overwatered. As a result, as much as 20 percent of all applied exterior water may represent overwatering.

In 1972, the estimated statewide *excessive* exterior water use resulting from overwatering totaled 272,000 acre-feet (335 cubic hectometres); this excessive use could increase to 418,000 acre-feet (516 cubic hectometres) in 2000 (Table 5). Table 6 shows that estimated residential overwatering in the Central Coastal, San Francisco Bay, and South Coastal hydrologic study areas totaled 190,000 acre-feet (234 cubic hectometres) in 1972 and could amount to 286,000 acre-feet (357 hectometres) in 2000.

Automatic sprinklers, except those with soil moisture override (sprinklers activated at predetermined soil moisture conditions), are feasible for ordinary home use. The soil moisture override system is best for the irrigation of larger areas, such as parks. All automatic sprinkler systems need periodic adjustment, due to seasonal climatic variations, sprinkler head adjustment, and changes in infiltration rates. The readings from soil moisture testing devices must be carefully interpreted. Soil texture, depth of test, and type of plant are important considerations. Well-controlled, timed sprinkler systems would not entirely eliminate overwatering, but could reduce it by 50 percent.

Eliminating overwatering would not necessarily result in an equal net water savings. In many areas, this excess water is not irrecoverably "lost", because most of it percolates to usable ground water, where it is pumped and reused (although it may have a higher salt concentration). On some coastal areas, it may also help repel sea-water intrusion.

TABLE 5. ESTIMATED 1972 AND PROJECTED (2000) STATEWIDE LAWN OVERWATERING

Year	Total applied lawn water		Overwatering, percent	Overwatering, quantity		Potential Savings (decrease of 50%)	
	1,000 acre-feet	Cubic hectometres		1,000 acre-feet	cubic hectometres	1,000 acre-feet	cubic hectometres
1972	1,360	1,678	20	272	336	136	168
2000*	2,090	2,578	20	418	516	209	258

*Based on Series D-100 population projection for 2000 (Bulletin 160-74, "The California Water Plan — Outlook in 1974").

TABLE 6. ESTIMATED RESIDENTIAL OVERWATERING, CENTRAL COASTAL, SAN FRANCISCO BAY, AND SOUTH COASTAL HYDROLOGIC STUDY AREAS 1972 AND 2000

HSA	Total applied lawn water, 1972		Overwatering, 1972		Total Applied lawn water, 2000*		Overwatering, 2000	
	1,000 acre-feet	cubic hecto-metres	1,000 acre-feet	cubic hecto-metres	1,000 acre-feet	cubic hecto-metres	1,000 acre-feet	cubic hecto-metres
Central Coastal	47	58	9	11	95	117	19	23
San Francisco Bay	266	328	53	65	431	532	86	106
South Coastal	638	787	129	158	905	1,116	181	223
TOTALS	951	1,173	190	234	1,431	1,765	286	352

*Based on Series D-100 population projection for 2000 (Bulletin No. 160-74, "The California Water Plan — Outlook in 1974").

In many parts of the State, percolating excess water may help replenish a drawn-down ground water basin. On the other hand, in other areas — particularly along coast — excess water may percolate to unusable ground water basins or to the ocean, where it is of no further use.

Even where excess water can be reused, it must be pumped, treated, and distributed to consumers, all of which results in additional costs. Such redistribution of once-used water also wastes energy.

Reducing Evapotranspiration

In California, about 70 percent of the applied exterior water is consumed through evapotranspiration (ET) by lawns, ornamentals, and home gardens. A meaningful reduction in ET would require extensive reductions in the high-water-using plants used by most California homeowners — at the moment a highly improbable and impractical measure. Moreover, little data on the types of plants growing on public and private land exists; accordingly, the potential water savings from such a change cannot be estimated.

Certain plants native to California, e.g., yucca, mountain lilac, sage, elderberry, California poppy, and native pines and oaks, require less water than many of the exotics brought here from other states and foreign countries. There are also low-water-using plants imported from other parts of the world with climates similar to California. However, most homeowners select plants on the basis of appearance, availability, rapid growth, hardiness, and cost — not on the basis of how much water they require. For that matter, few homeowners are even aware of the difference in water requirements among the many available varieties of plants, shrubs, trees, etc.

At the moment, little information on the various native plants and their water needs is readily available to homeowners. The best sources of such information are organizations such as the Rancho Santa Ana Botanical Garden of Claremont, Saratoga Horticultural Foundation of Saratoga, Los Angeles County Department of Arboreta and Botanic Gardens, and the California Native Plant Society, a statewide organization dedicated to the preservation of native flora.

Research, Testing, and Data Gathering. Establishing widespread use of low-water-using plants and reductions in overwatering would require programs to:

a. Determine the types of plants, trees, and shrubs in both public and private gardens.

b. Determine how much water is required by various plants during the growing season.

c. Promote research on the development of hybrids that would combine the most desirable features of native plants and exotics.

d. Develop an inexpensive, reliable soil-moisture indicator that could be used by homeowners and professional gardeners.

Because less water is used for lawns and landscaping, per capita water use for apartment buildings is significantly lower than for single-family homes

Careful control of lawn and landscape watering will reduce runoff into gutters and streets

e. Collect and dissiminate information about the use of plants with low water requirements under various soil and climatic conditions.

f. Inform the general public, legislators, nurserymen and gardners, etc., on the advantages of growing plants that require little water.

Implementation

A successful statewide program to reduce exterior water use will require the cooperative efforts of the public and, particularly, public and private agencies and organizations. Agencies might take the lead in promoting the following suggested ideas:

a. The use of water-saving devices, such as automatic sprinkler systems, and the use of soil-moisture testers, should be encouraged.

b. When new homes are constructed, desirable native plants should be protected.

c. Government agencies should set an example by using low-water-using plants along highways and around public buildings.

d. Parks, golf courses, and other public facilities that normally require large quantities of water should be designed to use native or low-water-using plants. El Dorado Park in Long Beach is an example of a park containing such plants. It uses less than 1 acre-foot per acre (0.3 cubic metres per square metre) per year for irrigation; other parks in the area require 3 or more acre-feet per acre (0.9 cubic metres per square metre) per year. Eventually, irrigation of El Dorado Park may be discontinued.

e. Demonstration gardens and landscaping that use little water could be established by state and local agencies as part of a statewide educational program. An example is the "Water Conserving Garden" at the Marin County Civic Center in San Rafael.

f. State agencies should cooperate with professional groups, such as the California Association of Nurserymen, to educate the public in the use of native and low-water-using plants and improved watering habits.

Governmental water uses include irrigation of parks and landscaping

Commercial and Governmental Water Savings

Because commercial and governmental water uses are similar, the two categories were combined for this discussion. The two principal commercial and governmental water uses are sanitation and landscape watering; in 1972, the statewide combined total use for these categories was about 700,000 acre-feet (860 cubic hectometres). Unless effective water conservation measures are taken, this total may increase to 1 million acre-feet (1,230 cubic hectometres) by year 2000.*

The opportunities for water savings are essentially the same as those in the residential category. Assuming the same relationship between the quantities used for interior and exterior purposes, implementation of the water conservation measures discussed in the two preceding sections** would result in statewide water savings in year 2000 of about 150,000 to 300,000 acre-feet (185 to 370 cubic hectometres) per year.

*Assuming growth of water demands in accordance with Series D-100 population projection (Bulletin No. 160-74, "The California Water Plan — Outlook in 1974"; November 1974.)

**See "Residential Interior Water Savings" and "Residential Exterior Water Savings"; pp. 16 through 25.

Government agencies should set an example by implementing water saving practices at their facilities wherever possible. Some state agencies are planning to initiate such actions in the near future.

Industrial Water Conservation

Some decline in unit water intake is expected over the next decade because of governmental regulations on the disposal of waste water. Moreover, changes in water prices could cause additional reductions in the rate of water intake.

The Federal Water Pollution Control Act Amendments of 1972 (Public Law 96-500) stated that, as a national goal, the discharge of pollutants into navigable waters must be eliminated by 1985. The Act requires industry to implement the best practicable waste treatment technology by July 1, 1977 and the best available technology economically achievable by July 1, 1983. Where industrial wastes are collected and treated by public agencies, the industry must repay all costs properly allocated to the industrial function, based on the volume and character of the wastes.

In many instances, the stringent treatment requirements for waste water disposal will provide incentives to industry to reduce unit water intake by either reusing waste water or changing certain production processes, or both. Some California industries have already made such changes because of the strict waste discharge requirements imposed by the Porter-Cologne Water Quality Control Act of 1969 and earlier legislation.

As discussed under "Water Pricing",* industrial users have commonly been favored by pricing policies that include reductions in unit price for large quantity deliveries. These pricing policies have generally been followed to encourage economic development. However, due to the increasing costs of water development and the high cost of energy required for delivery, the costs of supplying water are rising, and unit price increases will be required in some parts of the State.

Moreover, current water pricing systems should be examined for possible changes that could promote water conservation. Although communities continue to be concerned with a healthy, viable economy, the question of equity in water pricing must be addressed. Therefore, the elimination of reduced rates for large water users should be considered, and appropriate rate changes should be made.

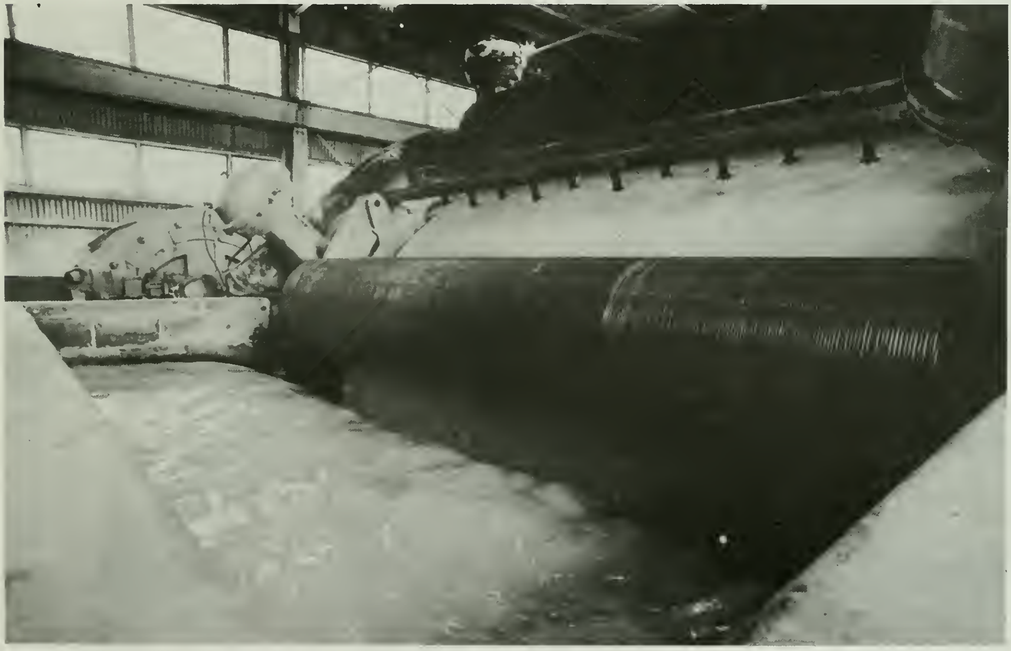
*See page 31.

Compared with other manufacturing costs, the cost of water to industry is generally low. A 1972 report prepared for the National Water Commission contained the following data:[5]

Industry	*Nationwide average water cost as a percentage of gross income*
Steel	0.59
Paper	1.46
Petroleum	1.95
Chemicals	1.33

As the price of water is increased and becomes a more significant element of total operating expenses, industries are expected to reduce fresh water intake.

Conservation measures include not only increased in-plant reuse and reduction of use but also the use of treated sewage and industrial waste water. The location of new industries should in-



Water used to convey pulp in the manufacturing of Fibreboard **photo courtesy of Kaiser Industries**

clude consideration of areas where treated effluent can be made available. In addition, the increased use of saline and brackish water should be considered.

It is impossible to predict the magnitude of statewide industrial water savings that might result from waste discharge controls, water price changes, and other economic factors. However, a number of California industries have already begun to reduce water intake. Several examples are presented in the following paragraphs:

1. A primary metals plant may require from 30,000 to 60,000 gallons (113,000 to 228,000 litres) of water per ton of finished steel. A California plant has reduced this requirement to as little as 1,400 gallons (5,300 litres) per ton.[6]

2. The petroleum processing industry has traditionally used large quantities of water. However, there is a wide range of use within each class of plant. Expressed in terms of water discharged per barrel of crude oil processed: for cracking plants, the range is about 10 to 50 gallons (38 to 190 litres); for lubrication-oil plants, about 20 to 80 gallons (76 to 304 litres); and for petrochemical plants, about 15 to 60 gallons (56 to 224 litres).[7]

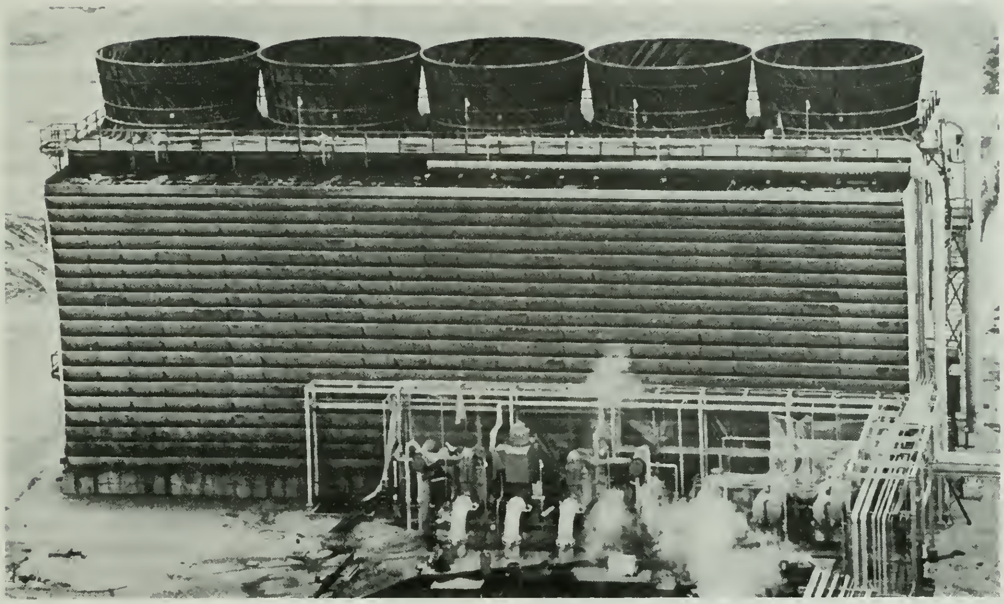
3. As much as 14 gallons (53 litres) of water may be used to produce one pound of carbon black. However, some plants have reduced this requirement to ¼ gallon (0.9 litre) of water.[6]

4. A paperboard plant began a water conservation program in 1972. Clarifiers were installed to enable increased water reuse, and water intake was reduced from 3,960 gallons (14,990 litres) per ton of paper products to 2,920 gallons (11,050 litres), a reduction of 26 percent. The cost of developing this process was $54,000 — for equipment, mechanical changes, labor, and experimentation.[8]

5. A plant processing animal by-products drastically reduced fresh water intake in less than 2 years. Instead of using fresh water to wash down the plants, they began using recycled waste water, thereby saving 281,000 cubic feet (7,950 cubic metres) at one plant and 129,300 cubic feet (3,660 cubic metres) at another. At each plant, fresh water intake was reduced about 30 percent.[9]

6. At a fruit and vegetable processing plant, bulk unloaders were installed to reuse conveyance and rinse waters. Screening facilities were enlarged from 3 screens with a single passover to a 12-screen system. All flow is now screened twice to remove as many solids as possible, which are then added to the product. The program was instituted during the

Water used to process olives



Water used for cooling

1974 season; data on actual water savings were not available at this time.[10]

7. In a tomato-processing plant, extractors were installed to reduce the loss of pulp into waste water. The recovered pulp is used in the production of sauce, paste, and catsup. In addition, bulk unloaders were installed to hydraulically handle the raw material. The unloading systems reuse waste water from the conveyor system and extractors, thus reducing waste water discharge by 10 to 15 percent, and at the same time reducing fresh water intake.[10]

These examples demonstrate that in many cases, industrial water use can be greatly reduced on an individual basis. Water pricing and waste discharge controls are effective means of motivating industries to make the necessary changes. Water supply agencies are responsible for initiating actions on pricing policy changes. They should also involve themselves directly or indirectly in waste discharge controls. They should be ever watchful and concerned about the effect of waste water disposal on their supplies and the potential for reclamation and reuse of waste water. This is particularly important in regard to industrial water use because industry has both the greatest potential for producing toxic pollutants and the greatest potential for use of reclaimed water. Wherever practical, the water supply agency and the sewage treatment agency management and operations should be coordinated. This would increase the awareness of the value of waste water.

Other Methods of Water Conservation

Other methods of water conservation include leakage repair, pricing and metering, education, and new technology. These are discussed in the following paragraphs.

Leakage Repair

Leaks may occur in a water purveyor's distribution system or in the consumer's system following delivery.

Leaks in distribution systems waste both water and energy, and can also undermine roads and other structures. Although the leaking water may percolate to a usable aquifer, it must be pumped, treated, stored, and, usually, pumped again to consumers. In a 1971 report for the National Water Commission, Howe et al estimated that the nationwide loss through leaks in utility systems is about 12 percent of distributed water, and that 9 percent could be saved.[11]

The report lists age, construction materials, physical and chemical soil properties, water properties, water pressure, and improper maintenance as the principal causes of such leaks. The report also lists, in order of importance, the types of avoidable leakage.

a. broken water mains and joints
b. active service leaks (between the main and the customer's meter);
c. leakage from hydrants;
d. inactive service leaks;
e. sewer flusher leaks.

In addition to these losses, water may also leak from a water purveyor's storage and main trunk facilities.

Few major California utilities have actual leak detection and repair programs. Instead, they keep accounts of where and how much water is used, and periodically replace old pipe or line it with concrete. Whereas the water accounting system helps detect some leaks, most are reported by concerned citizens.

Most California utilities estimate leakage losses of 8 percent or less — lower than the nationwide average of 12 percent. On the basis of the experience of East Bay Municipal Utility District (EBMUD), the estimated statewide water loss through repairable leaks in utility systems is 190,000 acre-feet (234 cubic hectometres) per year.[12]

Of three Southern California utilities, none reported that leakage was a problem. They reported average losses of 4 to 8 percent — again well below the nationwide average. The low rate of loss was attributed to (a) relatively new distribution systems, and (b) systematic maintenance, including replacement or concrete-lining of older pipe. However, none of the three has a leak-detection program; all three rely on reports from consumers and estimates to determine where water is being lost.

In 1974, EBMUD began using portable sonic detectors to monitor leaks in its distribution system. As of November 1975, the utility had surveyed 50 percent of its 3,200-mile (5,150-kilometres) system; the leaks discovered and repaired had accounted for an estimated loss of 4,500 acre-feet (5 cubic hectometres) per year, compared to annual average consumption of 234,000 acre-feet (289 cubic hectometres) per year.[12]

Households Leaks. There are an estimated 70 million residential faucets, toilets, and appliance water connections in California; by 2000 there may be 110 million. In addition to wasting water, household leaks waste energy and increase sewage treatment loads. Leaks of hot water require that additional water be heated and thus require additional energy. Moreover, most of the water lost through leaks enters the sewage system and is returned to a treatment plant.

The most common types of household leaks are from faucets and toilet mechanisms. Today, faucets and toilet mechanisms that eliminate or reduce leakage are available.

a. **Faucets.** The ordinary faucet is provided with a rubber gasket or washer that creates a watertight seal. When the washer becomes worn, the seal is lost and the faucet begins to drip. In most faucets, the leak can be repaired by merely replacing the washer.

A recent innovation is the washerless faucet. The initial cost ($20 to $40 for a washerless faucet) is higher than an ordinary faucet, which usually costs $5 to $10. However, the washerless fixture is usually guaranteed to be trouble-free for 10 to 15 years.

b. **Toilets.** Toilet leaks are most often caused by a worn supply valve, an improperly seating tank ball, or a leaking tank float. Although any of these can be easily repaired, the malfunction often goes undetected. Toilets can now be retrofitted with a leak-signalling ball cock, which eliminates the older type float and, by its refilling noise, alerts the homeowner of leaks. Colored dye placed in the tank can also be used to detect leaks.

Toilets with flushometer valves are commonly used in commercial and industrial installations. Such toilets have no tank; instead, the bowl is flushed by a direct flow from the water line. Leaks from flushometer valves are usually visable; on the other hand, if the valve is improperly seated, leaks may go undetected.

No factual data on leaks in households and commercial-industrial installations are available, and no meaningful estimate of the statewide water loss resulting from such leaks can be made. Apparently, most leaks continue unrepaired because of the high cost of plumbing service. Because water is usually inexpensive, most consumers ignore the leak to save the cost of having it corrected.

A Southern California plumbing firm that promotes leak detection and repair provided the following observations:

1. About 70 percent of the requests for leakage repair are from residents of single-family homes; the remainder are from apartment dwellers and commercial-industrial establishments. Because most apartment rental costs include the cost of water, apartment dwellers have little economic incentive to repair leaks.

2. By the time most persons call a plumber, the leak is quite large.

3. The average cost of a service call by a plumber is $15; the cost of materials varies from less than $1 for a faucet washer to $15 for a replacement valve. The average cost of labor and material for repairing a household fixture is about $20.

4. Leaks frequently occur between the water meter and the house. Such leaks can be unknown to the householder and are often quite large.

5. Unless they have maintenance personnel, owners of commercial-industrial establishments are usually quite lax about repairing leaks.

6. The market for leak detection and repair service is virtually untapped.

Research, Testing, and Data Collection. The following measures are suggested as methods to encourage increased repair of water leaks in distribution systems, households, and commercial-industrial installations.

1. A model program for detection and repair of leaks in water distribution systems could encourage utilities and other water purveyors to establish programs of their own.

2. A similar model program for householders, property managers, and commercial-industrial users could encourage them to follow suit.

3. Further research on faucets, toilets, and other plumbing fixtures that eliminate or minimize leaks could be encouraged.

4. The effectiveness and problems resulting from conservation programs and pertinent local ordinances could be monitored. One such ordinance is No. 74-2 of the Goleta County Water District, which prohibits:

> " . . . the escape of water through breaks or leaks within the water user's plumbing or distribution system for any substantial period of time within which such break or leak should reasonably have been discovered and corrected. It shall be presumed that a period of eight hours after the water user discovers such leak or break, or receives notice from the district of such leak or break, whichever occurs first, is a reasonable time within which to correct such leak or break."

Implementation. 1. Utilities should undertake leak detection and repair programs for their distribution systems. DWR will examine water systems through the State and recommend appropriate measures to ensure that actions are taken.

2. Government agencies at all levels should establish similar programs for their plumbing installations.

Pricing and Metering

Pricing. The principal goal in setting rates for water is to secure sufficient revenue to offset all costs, and in the case of commercial companies, to achieve a profit. Other goals should be that the pricing system is equitable and discourages waste. Although what is "equitable" and what is "waste" might be variously defined, examination of current pricing systems indicates that little attention has been given to either in most cases.

Seven common pricing systems are briefly described in Table 7. There are many others, including rates based on meter size and separate rates for different types of uses, but those described in Table 7 represent the basic types. A flat rate and a declining block rate are least equitable and do not promote the elimination of waste. Although the uniform rate can be considered equitable, it often has only minor effect on waste. The increasing block rate and the peak load, or seasonal, rate may offer the greatest opportunity for discouraging waste.

The exact relationship between water price and rate of use has not been clearly established. Documentation of case experiences of rate-of-use changes with increases in price is rare and usually incomplete. Although dissertations presenting economic theory abound, actual experiences sometimes appear to contradict the assertions in some of these that there will be significant and continuing reductions in water use with increase in price. However, it is only logical to assume that at some level, price will have a distinct impact on rate of use.

The key to an effective water pricing policy from the standpoint of conservation is to make it clear to the user that he can save money by minimizing water use. Therefore, the increase in water costs for quantities above the reasonable minimum required must be great enough to attract attention and become a factor of special concern in his budget or operating expenses. Pricing systems such as the increasing block rate and the peak load, or seasonal, rate offer the opportunity to increase an awareness of the relaionships between quantity used and cost.

Ad valorem taxes for water are not visible as part of the water bill. Such taxes are often imposed in recognition of the general benefit of capital improvements to a water system, such as providing water for fire fighting. However, in the interest of water conservation, they should be discontinued

TABLE 7. SUMMARY OF PRICING SYSTEMS

Type of System	Definition and Comments	Degree of Equity	Discouragement of Waste
Metering	1. Not generally thought of as a pricing method, it is essential to effect most pricing programs. 2. Installation of meters in nonmetered areas usually results in decrease in consumption of at least 25%. 3. About 90% of California's population resides in metered areas.	Required for Equity	Yes
Flat Rate	1. Usually found in unmetered areas; each customer is charged the same regardless of the amount of water used. 2. Sometimes the rate is varied according to the size of delivery line. 3. Easy for utilities to manage.	Not Equitable	No
Declining Block Rate	1. Customer is charged a certain amount for an initial quantity or "block" of water. The rate for succeeding blocks decreases with each block. 2. Most common rate structure in California.	Not Equitable	No
Uniform Rate	1. Each unit of water costs the same 2. Second most common rate structure in California.	Equitable	Minor
Increasing Block Rate	1. Customer is charged a certain amount for an initial quantity or "block" of water. The rate for succeeding blocks increases with each block. 2. Rarely used in California.	Equitable	Yes
Peak Load, or Seasonal, Rate	1. Customer is charged a uniform rate for a certain quantity of water. This quantity is usually based on the reduced lawn irrigation season use or on the average demands on the water distribution system. 2. Quantities used above the amounts determined in (1) are charged at a higher rate.	Equitable	Yes
Lifeline Rate	1. State law requires that the rate for a certain amount of energy service ("lifeline" amount) cannot be increased until rates for amounts above the "lifeline" amounts are raised 25%. 2. The City of Los Angeles recently established special water and energy rate categories for certain low income senior citizens. (For water, the first 900 cubic feet consumed each month is discounted 50%.)	Equitable	Yes

wherever practical and the revenue collected through the regular rate system.

In some areas, charges for sewage treatment are included in the water bill. This is justified on the basis that the size of sewage treatment facilities is a function of the quantity of water to be treated. It serves the purpose of encouraging conservation in the manner indicated above, i.e., by making the water bill significant to the user.

Metering. Metering serves two purposes related to water conservation. First, installation of meters has reduced water use by at least 25 percent in most cases (an example of the significance of creating an awareness on the part of the users of a relationship between quantity used and cost). Second, metering is necessary for any pricing system other than a flat rate. In California, about 90 percent of the population lives in metered areas. Most of the Central Valley is not metered.

The lifeline rate concept has received considerable attention recently, with its application to gas and electricity pricing. Under this system, special discounts are given to senior citizens with low income. The City of Los Angeles has established a special water rate using this concept, whereby the first 900 cubic feet of water consumed per month is discounted 50 percent. These policies should be instituted elsewhere.

Education

Although not a direct means of water conservation, education is an essential step toward implementation of direct conservation measures. For example, the statewide use of low-flush toilets and other water-saving devices and appliances would save large quantities of water. Yet, if consumers are to be receptive to the costs or inconveniences of water saving, they must be informed of the benefits and be convinced of the need to save water. In the same vein, lawmakers must be fully informed if they are to consider legislation concerning the use of low-water-using devices and fixtures.

Views about the immediate availability of water and user habits are deeply entrenched in the average consumer. Education is needed to overcome the commonly held view that water is abundant and that wasted water is of little consequence. Accordingly, a well-planned educational program is needed to create a "water conscience".

Conservation education should be a long-range program intended to promote a conservation ethic. The first objective should be to convince legislators, city and county officials, and managers and directors of water agencies and utilities of the need for long-range educational programs. These decision makers must understand water conservation if, among competing demands for funds, they are to allocate funds and resources for such programs. The support of professional groups and labor unions, such as the American Society of Plumbing Engineers, the American Water Works Association, the California Association of Nurserymen, and local plumbers unions, would be essential. Environmental groups could also wield powerful support for such a program.

Almost 25 percent of California's 21 million residents are school children — in kindergarten, primary, and secondary schools. Water conservation should be included in the public school curriculum as part of an effort to instill the careful use of all resources.

Advertising is also a powerful medium, and all citizens are exposed to radio, television, newspapers, and magazines. The cooperation of these media would be an essential part of the program. Information can also be disseminated at a more personal level through public meetings, conferences, seminars, and workshops.

New Technology

As shown in Table 2, the use of the water-saving plumbing fixtures and devices discussed previously in this chapter could result in reduced interior water use. Additional potential for reducing interior water use lies in (1) the development of new technology and (2) new patterns of interior water use.

For example, all of the water supplied to residences is of sufficient quality for human consumption, but most of it is used for washing and disposal of wastes. Only about 4 percent of the water delivered to homes is used for drinking and cooking. Therefore, if water could be recycled within the home and reused for cleaning and waste disposal, substantial savings could result. Today, new materials that could simplify the washdown and cleaning of toilet bowls and sinks are available. Their use, however, may depend on consumer acceptance.

The appliances and systems discussed in the following paragraphs would substantially reduce interior water use, perhaps by as much as 300,000 acre-feet (370 cubic hectometres) per year by 2000, if they were used to the maximum possible extent throughout the State. All of them are not totally new, but none is in widespread use in the United States.

New Toilets

Toilets offer the largest individual potential water savings. Four modifications are described in the following paragraphs.

Dual-flush toilets provide an optional low-volume flush for liquid waste and a higher-volume flush for solid waste. Manufacturers claim liquid flush reductions of up to 75 percent of the conventional flush. They depend on the user to choose the flush volume. Most designs thus far have concentrated on modifying existing tank toilets.

Dual-flush toilets rank very high in cost-effectiveness analysis. Limited field testing has demonstrated their mechanical feasibility and consumer acceptance, but Uniform Plumbing Code (UPC) requirements have not been met for the depth of water remaining in the trap after the lower volume flush.

The English toilet is a modified conventionally designed toilet used widely in Europe; some are dual flush. It operates on 2 gallons (8 litres) per solid waste flush and 1 gallon (4 litres) per liquid waste flush, but it does not wash down the bowl as required by American standards of design, and the reduced volume of water may require a steeper slope of waste pipe than the UPC now requires to carry solid wastes and prevent clogging.

Vacuum or air-pressure toilets use either a low vacuum or an injection of air to assist in removing waste from the bowl. They operate on 1.5 to 2 quarts (1.4 to 1.9 litres) of water per flush — up to 90 percent less than conventional toilets and 80 percent less than water-saving toilets. Compared to the conventional gravity-flow-waste-discharge system, the vacuum system is complicated because it requires more pumps and valves. Moreover, it requires energy to activate the necessary air pressure. Vacuum toilets, which can be used with existing sewage-collection systems, have been used in Europe for some years.

Chemical, oil-carriage, composter, and incinerator toilets are not generally acceptable for widespread use in populated areas, because of the high maintenance required. However, they are well suited for remote or rural areas or as temporary facilities at construction sites.

Shower Heads

The low-flow shower head (Table 2) uses a minimum flow of 2 to 3 gallons (7.6 to 11.4 litres) per minute. A more advanced shower head, which mixes air with water and propels the mixture, uses a water flow of 0.25 to 0.5 gallons (0.95 to 1.9 litres) per minute — a reduction of over 75 percent from even the low-flow shower. The reduced flow will also save energy, although some energy is required to produce the compressed air. This new shower head will require testing to determine consumer acceptability.

Kitchen and Lavatory Faucets

Conventional faucets deliver 4 to 5 gallons (15 to 19 litres) per minute. Faucets that deliver only 0.5 gallons (1.9 litres) per minute — even less than the water-saving faucets shown in Table 2 — have been used successfully in commercial buildings. However, the acceptability of such faucets for residential use has not been tested.

Premixed Water Systems

In most homes, water is wasted while the householder opens both the hot and cold water taps to obtain the desired water temperature. This wastage could be reduced by use of insulated hot water pipes or by a premixed system that uses an electronic solenoid valve. The premix system, which mixes hot and cold water near the water heater, will deliver water of several different temperatures at either high or low flows. The manufacturer reports a 33 percent reduction in kitchen, lavatory, and shower use and in hot water required. The premix system may require refinement to conform with applicable building and plumbing codes.

Grey Water Systems

A grey water system collects, disinfects, filters, and stores household waste water (from kitchen, shower, and lavatory) and reuses it for toilet flushing. In most homes, sufficient waste water could be collected to meet flushing requirements, and interior demands could be reduced by about one-half.

The system has been successfully demonstrated and is considered acceptable by the public. However, its use would entail greater initial and operating expense and energy consumption than conventional systems.

Implementation

1. The systems described in the preceding paragraphs offer significant potential savings of both water and energy. However, their effectiveness requires additional evaluation, and the costs to consumers must be determined. Some of the systems may need further refinement to meet local codes and to obtain consumer acceptance.
2. The applicability of local building, plumbing, and health codes to such systems should be evaluated.
3. The State could participate in monitoring projects to assess conservation of water and energy.
4. The State could identify areas where additional new technology could be used to conserve water and energy.

Present Urban Water Conservation Practices

Few water utilities and other purveyors actively promote water conservation. When conservation measures are promoted, it is usually because a service area faces a shortage of supplies or because an overloaded waste treatment system requires reduced waste flows.

Conservation can be practiced in two basic ways: (1) mechanical, by which the consumer has little or no control over the amount of water used; and (2) user habit, by which the consumer directly regulates the amount of water used. In new or replacement construction, mechanical methods of conservation can be required by legal means such as plumbing code changes, whereas in existing structures, retrofitting can best be implemented on a voluntary basis. This degree of voluntary participation largely depends on aggressive promotion of water conservation measures.

User habits are principally influenced through education. Programs can be established to inform users that water conservation results in direct savings in both water and energy, which will, in turn, result in direct monetary benefits, i.e., lower utility bills. In addition, water conservation can produce indirect long-range benefits, e.g., expanding the use of existing water supply and waste disposal facilities, which, in turn, could defer the construction of new projects and facilities.

A number of water agencies have produced effective conservation campaigns. Some of these are described in the following paragraphs.

Washington, D.C. Suburban Sanitary Commission (WSSC)

In Hyattsville, Maryland, in 1970, a potential water-supply shortage, and a ban on new sewer connections caused by insufficient sewage treatment facilities, led to a moratorium on the construction of new homes. As a result, WSSC devised and began a comprehensive, imaginative program to reduce water use and waste flows. The campaign included consumer involvement and education, retrofitting of plumbing devices and appliances, and legal measures.

Consumer Involvement and Education

a. Water Saving Idea Contest, with United States Series "E" bonds as prizes.
b. Free distribution to all customers of residential interior conservation handbook, "It's Up to You."
c. Water-saving workshops for property owners.
d. Slide-speaker programs.
e. House-to-house distribution of information cards, buttons, stickers, bumper stickers.
f. Series of radio and TV spots.
g. Continuous newspaper publicity.
h. Poster contest, with U.S. Series "E" bonds as prizes.
i. Free distribution of a handbook, "Keeping the Garden Green".
j. Production of a film, "Drip", for schools and community groups.
k. Information about appliances, such as dishwashers and washing machines.
l. Organized "Camel Day", a one-day demonstration of minimal use of water with public participation.

Retrofitting and Leak Detection

a. Installation, maintenance, and testing of several types of toilet-tank inserts and shower-flow restrictors.
b. Free distribution of 890,000 plastic quart (0.95 litre) bottles for reducing water volume in toilet tanks.
c. Free distribution of 400,000 shower head flow restrictors.
d. Free distribution of 600,000 dye pills for detection of leaks in toilet tanks.

Legal Measures

a. Revision of the plumbing code to require pressure-reducing valves, water-saver toilets, and low-flow shower heads, and to set the maximum allowable faucet flow in new and replacement construction.
b. Compilation and maintenance of a list of approved water-saving devices.

The conservation campaign has resulted in annual water savings of 8,000 acre-feet (10 cubic hectometres).

Fairfax County, Virginia

Fairfax County, Virginia, has modified its plumbing code to set the following water-saver standards for a pressure at the fixture of 40 to 50 pounds per square inch (180 to 340 kilopascals):[13]

Tank toilets	3.5 gallons (13 litres) per flush
Flushometer toilets	3.0 gallons (11 litres) per flush
Urinals	3.0 gallons (11 litres) per flush
Shower heads	3.0 gallons (11 litres) per minute
Faucets	4.0 gallons (15 litres) per minute
Public use faucets	4.0 gallons (15 litres) per minute and self-closing
Car washes	must have approved recycling (existing installations must be retrofitted)
Continous flow equipment	flow in excess of 5 gallons (19 litres) per minute must have approved recycling.

The Fairfax County Water Authority also imposes a surcharge of $2 per 1,000 gallons (3,785 litres) on summer use that exceeds a specified winter use.

East Bay Municipal Utilities District (EBMUD)

In 1970, EBMUD, in the eastern San Francisco Bay area, estimated that per capita water demands had increased from 118 gallons (447 litres) per capita per day in 1950 to 205 gallons (776 litres) per capita per day. EBMUD determined to stop or reverse the trend. Towards this end, the utility prepared a report ("Water Conservation") containing 47 recommendations under three main headings:[14]

General public activities are primarily educational and list 16 ways to involve the public, such as: (a) redesigned water bills that consumers can readily understand; (b) full-time tours of schools by a mobile van with water conservation exhibits; and (c) construction of a native-plant garden to demonstrate the cultivation of plants with low water requirements.

Specific group activities list 17 recommendations for identifying and correcting excessive water use by commercial, industrial, and public-authority consumers. The recommendations are designed to (a) advise consumers of applicable codes and regulations; (b) discourage carelessness, leakage, and wasted water; (c) promote recycling and waste water reclamation; (d) reduce water use by public agencies, especially for such uses as street cleaning and fire-department training; and (e) encourage the use of low water-consumer plants in public areas.

District activities list 17 recommendations for modifying EBMUD operations or regulations. They include recommendations to (a) survey and correct water leaks in all District facilities; (b) eliminate excessive water use by the District, meter all District water uses, and provide stricter accounting measures; (c) advise and work with District employees on the conservation program; and (d) study the feasibility of reducing residential water use through such measures as providing leak detection and repair service, increasing the unit cost of water when individual residential use exceeds a predetermined level, and modifying metering-and-price structures for certain users.

This intensive conservation campaign has been in effect for three years. EBMUD reports that average per capita water use has dropped 5 percent from the use in 1970 but considers it "too soon to consider the results conclusive."

North Marin County Water District (NMCWD)

This Novato, California u.ility has begun a program to encourage water conservation in new residential construction. Currently, 226 new townhouse units have been equipped with low-flush toilets, shower flow controllers, faucet aerators, and insulated hot-water lines. The program also includes exterior water saving features, including (1) well-drained topsoil under all turf areas, (2) time-controlled sprinklers with low application rates, and (3) moisture sensors that override the time controls and turn off the sprinklers when the soil becomes sufficiently wet. Some native plants have also been installed. The initial cost of these features was about $200 per dwelling unit.[15]

NMCWD estimates the water-conservation measures will reduce annual water requirements in the townhouse area by 45 percent. So far, the program has been successful, and the District is considering an incentive policy that would provide reduced connection fees for developers who install water-conservation devices.

NMCWD also encourages the use of — and provides at cost — a shower flow-control insert and two types of toilet inserts. The District is now preparing a report listing all available water-saving devices and the names of the suppliers.

Goleta County Water District (GCWD)

GCWD in Santa Barbara County has adopted the most comprehensive water conservation ordinances in the United States. These ordinances, which supplement — but do not conflict with — the Uniform Plumbing Code and other applicable codes, stipulate the following:

1. In new and replacement construction, specified plumbing fixtures must be used for tank and flushometer type toilets, kitchen and lavatory faucets, showers, urinals, and other water-using devices.
2. Hot water pipes must be insulated; where embedded in concrete, hot-water pipes must be at least 3 feet from cold water pipes.
3. Runoff from residential or agricultural irrigation must be kept to the minimum.
4. Hosing of sidewalks, driveways, and other hard-surfaced areas is prohibited.
5. Breaks or water leaks must be repaired within 8 hours after discovery.
6. Unless approved in advance, routine flushing of sewers by government agencies is prohibited.[16,17]

In addition, GCWD is promoting a voluntary program to retrofit existing plumbing with devices and fixtures that use less water.

Sacramento Area Water Works Association (SAWWA)

Since 1958, the Sacramento Area Water Works Association has conducted an annual "Don't Be A Gutter Flooder" promotion, which is an intensive public educational program. The campaign takes place each summer -- the period of greatest water use. In 1974, the campaign was linked with the promotion of conservation of energy.

At the present time, 19 water companies are involved, together with the local Girl Scout Council, 12 newspapers, 9 radio stations, 3 television stations, an advertising agency, an outdoor advertising company, and bus advertising. Voluntary effort and public service are emphasized, and only the advertising agency is paid for its work in the campaign.

In 1974, goods and services valued at $24,000 were contributed, including 965 radio spots, 300 TV spots, 20 billboards, 183 bus ads, over 75 column inches of newspaper coverage, and 700 in-store display cards. In addition, 6,000 Girl Scouts distributed 100,000 information cards to area residents.

SAWWA believes that virtually every consumer in the combined service areas was reached by some phase of the campaign. However, because water is supplied on a flat-rate basis in the Sacramento area, the effect of the campaign is somewhat limited and difficult to evaluate.

Marin Municipal Water District (MMWD)

MMWD began a comprehensive water conservation program in recent years designed to minimize cost and inconvenience to consumers. Except for new construction, the program has been voluntary. In 1976, the occurrance of a dry year prompted the District to place mandatory controls on use of water for landscape watering, sidewalk cleaning, and car washing.

The water district credits its campaign of public education with the reduction of per capita use from 171 gallons (647 litres) per capita per day in 1970 to the present 160 gallons (606 litres) per capita per day. A retrofit program is expected to decrease per capita use in existing homes and businesses to 136 gallons (515 litres) per capita per day by 1984. In new homes and other construction per capita use is expected to be 117 gallons (443 litres) per capita per day.[18]

The retrofit program for present consumers includes free distribution and installation of water-saving devices as follows:

Showers. Free distribution of both flow-control inserts and low-flow shower heads. The type of device installed depends on the design of the shower assembly. Both devices restrict the flow to a maximum of 3.5 gallons (13 litres) per minute.

Toilets. Door-to-door distribution of dye pills for leak detection and weighted plastic bottles for tank installation.

Pressure Reducing Valves. MMWD encourages installation of pressure-reducing valves on domestic plumbing fixtures where needed to reduce water pressure to 50 pounds per square inch (340 kilopascals).

For the retrofit program, MMWD estimates the following costs *per acre-feet (1,233 cubic metres) of water saved:*

a. *Shower inserts:* $15.00
b. *Toilet inserts:* $28.64
c. *Pressure reducing valves:* $105.60

To encourage retrofitting, MMWD contacts consumers in two ways: (1) billing inserts, with a postage-paid return card to request water-conservation devices, and (2) a door-to-door canvass by college students.

In new construction, the conservation program requires such plumbing features as 3.5 gallon (13-litres) toilet tanks, 3 gallon (11-litre) per minute shower heads, and pressure reducing valves to restrict pressure to 50 pounds per square inch (340 kilopascals). Hot water pipes must be insulated, and hot water recirculating systems are required.

Plastic bottles for toilet tank installation distributed by Marin Municipal Water District

As part of the overall water-conservation program, MMWD will:

a. Evaluate landscaping plans in specified areas. In such areas, irrigation systems must be approved by MMWD also.
b. Evaluate all proposed water conservation measures.
c. Set recycling requirements for car-wash facilities.
d. Require the use of reclaimed waste water when it is available at reasonable cost.
e. Require the use of recycling and water-saving devices as made possible by advancing technology.
f. Provide technical help to large public and private irrigation consumers and recommend improved irrigation practices and landscape alterations.
g. Provide technical help to industrial and commercial consumers.
h. Conduct seminars and conferences to demonstrate water-saving techniques in the garden.
i. Conduct other educational programs.

As part of its consumer education program, MMWD has sponsored a low-water-using garden at the Marin County Civic Center.

Assessment of Potential Urban Water Conservation

Table 8 summarizes the quantities of water and energy that might be saved in California through use of the methods of water conservation discussed in this chapter. Conservation practices might be implemented by any of three basic methods:

1. *Voluntary* action by individual users.
2. *Institutional* action by government or water agencies, e.g., pricing and metering, educational programs, leakage repair programs, etc.
3. *Proscriptive* action, i.e., the imposition of laws and regulations.

As discussed previously, the various water conservation methods could result in numerous benefits — lower long-range water costs for consumers, energy savings, a reduced need for new water projects, and lower costs for water treatment. The principal disadvantage of lower urban water use is that water agencies could be faced with a repayment problem: If water demands dropped substantially, agencies and utilities might have to increase unit costs to cover expenses.

The possible means of implementation, along with the advantages and disadvantages of all the various methods of water conservation, are presented in Table 9.

TABLE 8

STATEWIDE SUMMARY OF POTENTIAL ANNUAL URBAN WATER AND ENERGY SAVINGS FOR YEAR 2000*

Type of Use	Water: Unit	Water: New	Water: Retro	Water: Total	Energy**: Unit	Energy**: New	Energy**: Retro	Energy**: Total
Residential								
Interior	1,000 acre-feet	310-569	365-882	674-1,451	millions of	3.3-4.4	4.5-6.0	7.8-10.4
	cubic hectometres	(382-702)	(450-1,089)	(832-1,791)	barrels of oil			
					$ millions	38-51	52-69	90-120
Exterior	1,000 acre-feet	73	136	209	—	—	—	—
	cubic hectometres	(90)	(168)	(258)				
Commercial &	1,000 acre-feet	45-90	105-210	150-300	—	(not estimated)		
Governmental	cubic hectometres	(56-110)	(129-260)	(185-370)				
Leakage from	1,000 acre-feet	—	190	190	—	—	—	—
Utilities	cubic hectometres		(234)	(234)				
SUB TOTALS	1,000 acre-feet	428-732	796-1,418	1,224-2,150	millions of	3.3-4.4	4.5-6.0	7.8-10.4
	cubic hectometres	(528-902)	(981-1,751)	(1,509-2,653)	barrels of oil			
					$ millions	38-51	52-69	90-120
Additional								
savings from	1,000 acre-feet	0-300	—	0-300	—	—	—	—
new technology	cubic hectometres	(0-370)	—	(0-370)				
TOTALS	1,000 acre-feet	428-1,032	796-1,418	1,224-2,450	millions of	3.3-4.4	4.5-6.0	7.8-10.4
	cubic hectometres	(528-1,272)	(981-1,751)	(1,509-3,023)	barrels of oil			
					$ millions	38-51	52-69	90-120

*Excluding industrial

**Energy savings are those directly connected with heating water. Energy savings due to reduced pumping by utilities are not included.

TABLE 9

METHODS OF URBAN WATER CONSERVATION IMPLEMENTATION, ADVANTAGES, AND DISADVANTAGES

Means to Reduce Water Consumption	Imple-mentation	Advantages	Disadvantages
Water saving plumbing fixtures in new and replacement construction.	Proscriptive	1. Mechanical devices render savings despite user habits. 2. Reduce waste water conveyance and treatment load.	1. Possible resistance to redesign and retooling to manufacture water conserving devices. 2. Drain pipe slope tolerances are more critical. 3. Initially, consumers may resist acceptance. 4. Initially, higher unit cost of water saving devices until demand increases production and reduces cost. 5. May cause blockage problems in marginal sewage collection systems.
Modification (retrofit) of existing plumbing fixtures.	Proscriptive Voluntary Institutional	1. Many devices are nominal in cost. 2. Enables water and energy conservation in existing facilities and therefore has potential rapid, widespread savings. 3. Water savings mechanically effected. 4. Reduces waste water conveyance and treatment load.	1. Inconsistent effectiveness of retrofit devices because of variable design and construction of existing fixtures. 2. Consumer removal or tampering with retrofit devices because of suspected poor performance. 3. Some devices require skilled installation and/or follow-up adjustment. 4. May cause blockage problems in marginal sewage collection systems.
New technology.	Voluntary Institutional	1. Greater water and energy savings than conventional designed devices. 2. Reduce waste water conveyance and treatment load.	1. Uncertain long-term effectiveness. 2. Consumer and institutional resistance to innovations. 3. Higher initial costs. 4. Conformance with existing codes and regulations; may require changes or variations. 5. May cause blockage problems in marginal sewage collection systems.
Efficient irrigation using automatic devices	Voluntary	1. Healthier plants. 2. Decreased maintenance. 3. Mechanical type savings.	1. Periodic adjustments required. 2. Expensive initial cost.
Native and other low-water-using plants in landscaping.	Voluntary Institutional	1. Established native and other low-water-using plants need little or no irrigation. 2. Established plants need little care.	1. General preference for exotic plants. 2. Narrow selection of native plants in nurseries. 3. Difficult to establish some low-water-using plants and general lack of knowledge on care. 4. Somewhat higher costs because native and other low-water-using plants are not readily available.
Leak detection and repair of water agencies' distribution systems.	Institutional	1. Reduces unaccounted water losses. 2. Reduces undermining damage to streets, sidewalks, and other structures.	1. Because leaking water often percolates to usable ground water, water agencies sometimes ignore losses. 2. Low cost of lost water may not equal cost of detection and repair.
Leak detection and repair of consumers' systems.	Voluntary Institutional	1. Can reduce other home repair costs such as those from wood rot. 2. Many leaks simple and inexpensive to repair. 3. Reduces operational costs.	1. Difficult to induce flat-rate consumers and apartment dwellers to repair leaks. 2. Could be expensive to consumer if he needs professional service.
Metering	Institutional	1. Easier to implement than some of the other suggested methods. 2. May induce consumers to begin conserving water.	1. Consumer objection. 2. High capital cost. 3. Requires changes in rate structure and billing procedure.
Pricing	Institutional	1. May be relatively easy to implement. 2. Can affect all customers. 3. Can be strong inducement to effect consumer savings.	1. Consumer objection. 2. Requires well designed pricing structure to achieve effective, equitable pricing. 3. Often require changes in rate structure, meter reading, and billing procedures.
Sewer service charges based on water consumption	Institutional	1. More equitable than flat-rate basis to pay operational cost of sewage treatment. 2. Achieve dual benefits of reduced water consumption and waste water flow.	1. Requires well designed rate structure. 2. Need to segregate inside and outside water consumption.
Education	Voluntary Proscriptive Institutional	1. Induces voluntary water conservation. 2. Changes long established, wasteful consumer habits. 3. Achieves long-lasting results by influencing younger generation. 4. Ensures greater success and acceptance of other water saving means.	1. Effective program requires coordinated efforts of local and state agencies.

Overall Impact Assessment

The nature and magnitude of the impact of water conservation in urban areas will vary on a case-by-case basis, depending on the measures implemented, location, water supply source, water quality, etc. It is beyond the scope of this report to identify all specific impacts of urban water conservation. However, some of the impacts — on water supply, water quality, and waste disposal — and some economic impacts that might be expected are discussed.

Water Supply

In addition to possibly delaying the need for additional major water projects, the decreased urban water demand might permit greater use of some of the existing supplies for such other purposes as ground-water-basin recharge, quality improvement, salinity control, power plant cooling, in-stream uses, and agricultural irrigation.

On the other hand, where excess water is currently reused — particularly in those areas where the ground water supply is recharged from waste flow, exterior overwatering, and leaking distribution systems, or where treated waste water replenishes surface water supply — the impact may be a decrease in the basic water supply historically available to some areas. However, most of California's population is located along the Coast, and existing systems discharge large quantities of water into the ocean after once-through use. In such areas, the opportunities for water savings through water conservation are substantial.

Water Quality

Generally, the quality of water supplies would remain unchanged; again, however, the impact will vary according to the circumstances. Reduction of water use and corresponding reduced imported water supplied could also reduce the total amount of salts brought into an area over a given period of time. In the case of inland wastewater discharges used to replenish ground water basins, water conservation may cause reduced discharges with higher salt concentrations; however, the quantity of salts remain the same.

Discharges to surface water supply systems could have similar effects. However, the beneficial or detrimental impacts of reduced water use cannot be generalized without thorough analysis of each situation.

Waste Disposal

Waste disposal could be affected in at least three ways:

1. The capacity of existing gravity-flow sewage collection systems to carry solid wastes could be affected by reduced flows. Theoretically, a reduced toilet flush of 3.5 gallons (13 litres) only slightly affects the performance of properly designed laterals, submains, and mains. However, when the existing carrying ability is already marginal, stoppages could occur. Only a field evaluation of any additional maintenance for individual lines in a system can fully determine what impact reduced flow will have. Where existing collection systems are overloaded, the effect would be beneficial.
2. The reduced flow will not substantially affect the efficiency of biological treatment, because the primary basis for facility design is the quantity of waste loading. On the other hand, lower flows would reduce the load on other plant facilities, such as settling tanks and clarifiers. The overall effect should be to extend the capacity of sewage treatment facilities.
3. Sewage plant effluent would have higher concentrations of salts and other materials. This could be a problem at point of discharge; however, the total salt loading would be reduced.

Economic

The direct monetary benefits in consumer water savings may be offset by increases in water prices required to make up the decrease in water utilities revenue. The impact of decreased water sales on individual utilities will vary. Schedules for repayment of debts and other long-term expenses are predicated on present and projected water sales. Operating expenses per service connection would not decrease significantly, except for the cost of energy. A comparison of the fiscal and operational situations of two typical Southern California utilities serving comparable highly urbanized areas illustrates the fiscal complications:

	Utility A	*Utility B*
Income		
Water Sales	75%	90%
Other	25%	10%
	100%	100%
Expenditures		
Salaries, Wages, and Related Expenses	29%	42%
Operating Expenses (primarily Water and Energy)	48%	18%
Debt Expense	5%	27%
Additions & Replacements	15%	8%
Payment to General Fund	3%	5%
	100%	100%

A decrease in water demand almost proportionately decreases Utility A's operating expenses, because most of its water is purchased from The Metropolitan Water District of Southern California (MWD). Utility A would use its locally produced water first because it is cheaper. It would also spend less on energy, but other expenses would stay almost the same. Although Utility A would receive less income from current and projected water sales, it would also spend less initially for MWD water.

MWD, in turn, would be faced with a problem because it has a high percentage of fixed costs. For MWD to generate sufficient revenue to repay its indebtedness and meet operating expenses it would probably have to either increase ad valorem taxes or raise the wholesale price of water.

Utility B, on the other hand, produces most of its own water, so a decrease in water sales causes a directly proportional decrease in water production costs (chiefly energy). However, because of its larger debt to repay for its facilities, a marked decrease in water sales causes repayment difficulties. Yet, revenues must somehow be increased, probably by increased water rates.

Fortunately, this potential fiscal dilemma would not occur immediately in most cases. The effect on per capita water demand of implementing water conservation measures would probably develop slowly over a period of time. Accordingly, some of the potential reduction in total revenues may not come about, because, as the population continues to increase, the number of customers would also increase. As population increases and utility revenue derived from a larger number of services increases, water rates should eventually stabilize, inflation permitting.

The major beneficial economic impact of water conservation will be to delay and reduce expenditures for development of additional water supplies. Additional supplies will be extremely costly, in both terms of facility development cost and the cost of energy to transport the water. The long-range economic benefits of maximizing the beneficial use of the current available supplies should be emphasized in public education programs on water conservation.

CHAPTER IV. METHODS FOR REDUCING AGRICULTURAL WATER USE

In general, California farmers can be credited with using effective irrigation methods. Often, however, farmers' irrigation methods are criticized without full understanding of the alternatives available to them. Moreover, "blanket" judgments that today's irrigation methods are inefficient are not completely valid. Irrigation specialists and crop farm advisors report that moderate underirrigation is common in many parts of the State.

Although irrigation efficiencies are generally higher in California than in other western states, various water conservation methods offer potential on-farm water savings. These methods should be evaluated on a case-by-case basis to determine opportunities for stretching presently developed water supplies.

This chapter presents a discussion of (1) various conservation practices that would reduce on-farm water use, and (2) improved water-district operations that might stretch the effective use of available water supplies. In Chapter 5, the probable results of implementation of these practices are evaluated.

Each of the following offers some potential for reduction in agricultural water use:

1. The irrigation method (sprinklers, drip, improving existing systems, and on-farm reuse systems)
2. Irrigation scheduling
3. Good drainage
4. Salt management
5. Rainfall utilization
6. Weed and phreatophyte control
7. Seepage control
8. Evaporation and transpiration suppression
9. Crop factors
10. System automation
11. Land Use
12. Institutional

The Irrigation Method

Tables 10 and 11 provide acreage summaries of irrigation methods in 1972 by hydrologic study area and by major crop. A significant change since 1972 is the increased use of drip irrigation — from the 30,000 acres (12,000 square hectometres) shown in Tables 10 and 11 to an estimated 70,000 acres (28,000 square hectometres), mainly in San Diego County and in the southern San Joaquin Valley.

The greatest on-farm water savings would result from selection of the most suitable irrigation method, along with design of an efficient system, proper installation, and regular maintenance.

Sprinkler Systems

Sprinkler systems generally produce higher farm irrigation efficiencies than those for comparable gravity irrigation (border, basin, or furrow) methods. Water can be saved using various types of sprinkler systems because:

1. Careful irrigation water management is possible where lands are not level.

2. Frequent, light irrigation applications are more easily made; for example (a) during plant germination, (b) for irrigating shallow-rooted crops, or (c) for crops planted in sandy soils.

3. Less applied water may be required to maintain acceptable soil-water salt levels.

4. Surface runoff is more easily reduced or eliminated.

5. On-farm open ditch water losses are eliminated.

A farm irrigation efficiency representative of gravity irrigation systems in California is estimated at 58 percent. This estimate is based on the wide variation in farm irrigation efficiencies resulting from many types, uses, and management levels of gravity irrigation systems. A similarly derived efficiency for sprinkler systems was estimated at 76 percent. The 18-percent higher efficiency of the sprinkler method is accounted for largely by reduced runoff, elimination of seepage losses from open ditches, and reduced deep percolation.

About 7.4 million acres (3 million square hectometres) in California are irrigated by gravity methods, and 1.6 million acres (650,000 square hectometres) are irrigated with various types of sprinkler systems. Although the use of sprinklers is increasing, they are used on only 17 percent of California's irrigated acreage today. Gravity irrigation methods serve about 82 percent.

Tables 10 and 11 indicate the types of sprinkler systems presently being used. On about 70 percent of the irrigated area served by sprinklers, hand-moved equipment, with a relatively low initial cost, is used. The more costly permanent systems are used on about 20 percent, and intermediate-cost mechanical-moved sprinkler systems are used on about 10 percent.

TABLE 10

IRRIGATED LANDS IN CALIFORNIA BY IRRIGATION METHOD, 1972*

(1,000's of acres)

Hydrologic Study Area	Total Irrigated Acreage	Surface Irrigation					Sprinkler Irrigation				Drip Irrigation	Sub Irrigation
		Wild Flood	Border	Basin	Furrow	Total	Solid Set	Hand Move	Mech. Move	Total		
NC–North Coastal	250	–	60	40	10	110	10	110	20	140	–	–
SF–San Francisco Bay	100	–	10	–	20	30	30	40	–	70	–	–
CC–Central Coastal	450	–	30	–	220	250	30	160	10	200	–	–
SC–South Coastal	430	–	40	–	170	210	40	140	20	200	20	–
SB–Sacramento Basin	1,530	100	650	200	320	1,270	20	200	20	240	–	20
DC–Delta Central Sierra	820	–	280	30	370	680	20	40	10	70	–	70
SF–San Joaquin Basin	1,360	–	770	20	430	1,220	40	80	10	130	–	10
TB–Tulare Basin	3,170	–	1,350	20	1,300	2,670	120	350	20	490	10	–
NL–North Lahontan	140	100	10	30	–	140	–	–	–	–	–	–
SL-South Lahontan	80	10	30	–	10	50	–	–	30	30	–	–
CD–Colorado Desert	720	–	420	–	300	720	–	–	–	–	–	–
Statewide Total	9,050	210	3,650	340	3,150	7,350	310	1,120	140	1,570	30	100
Percent of Total	100	2	41	4	35	82	3	12	2	17	–	1

*"Irrigation in California", Report to State Water Resources Control Board, June 1975, by J. Ian Stewart, Division of Agricultural Sciences, University of California, Davis.

TABLE 10

IRRIGATED LANDS IN CALIFORNIA BY IRRIGATION METHOD, 1972*

(METRIC UNITS)

(1,000's of square hectometres)

Hydrologic Study Area	Total Irrigated Acreage	Surface Irrigation					Sprinkler Irrigation				Drip Irrigation	Sub Irrigation
		Wild Flood	Border	Basin	Furrow	Total	Solid Set	Hand Move	Mech. Move	Total		
NC–North Coastal	101	–	24	16	4	44	4	45	8	57	–	–
SF–San Francisco Bay	40	–	4	–	8	12	12	16	–	28	–	–
CC–Central Coastal	182	–	12	–	89	101	12	65	4	81	–	–
SC–South Coastal	174	–	16	–	69	85	16	57	8	81	8	–
SB–Sacramento Basin	615	40	260	80	130	510	8	81	8	97	–	8
DC–Delta Central Sierra	328	–	110	12	150	272	8	16	4	28	–	28
SJ–San Joaquin Basin	548	–	310	8	174	492	16	32	4	52	–	4
TB–Tulare Basin	1,283	–	546	8	530	1,084	49	142	8	199	4	–
NL–North Lahontan	56	40	4	12	–	56	–	–	–	–	–	–
SL–South Lahontan	32	4	12	–	4	20	–	–	12	12	–	–
CD–Colorado Desert	290	–	170	–	120	290	–	–	–	–	–	–
Statewide Total	3,649	84	1,468	136	1,278	2,966	125	454	56	635	12	40
Percent of Total	100	2	41	4	35	82	3	12	2	17	–	1

*"Irrigation in California", Report to State Water Resources Control Board, June 1975, by J. Ian Stewart, Division of Agricultural Sciences, University of California, Davis.

TABLE 11

IRRIGATION METHOD BY CROPS, 1972*
(1,000's of acres)

Crop	Total Irrigated Acreage	Surface Irrigation						Sprinkler Irrigation			Drip Irrigation	Sub Irrigation
		Wild Flood	Border	Basin	Furrow	Total	Solid Set	Hand Move.	Mech. Move.	Total		
Alfalfa	1,240	—	970	80	30	1,080	—	110	50	160	—	—
Pasture	1,340	210	910	—	—	1,120	20	180	20	220	—	—
Rice	350	—	160	190	—	350	—	—	—	—	—	—
Sugar beets	340	—	—	—	270	270	—	60	10	70	—	—
Misc. Field	3,030	—	1,090	—	1,490	2,580	—	320	30	350	—	100
Misc. Truck	920	—	—	—	740	740	100	70	10	180	—	—
Misc. Orchard	1,280	—	370	60	320	750	120	360	20	500	30	—
Vineyard	550	—	150	10	300	460	70	20	—	90	—	—
Statewide Totals	9,050	210	3,650	340	3,150	7,350	310	1,120	140	1,570	30	100
Percent by Method	100	2	41	4	35	82	3	12	2	17	—	1

*"Irrigation in California", Report to State Water Resources Control Board, June 1975, by J. Ian Stewart, Division of Agricultural Sciences, University of California, Davis.

TABLE 11

IRRIGATION METHODS BY CROPS, 1972*
(METRIC UNITS)
(1,000's of square hectometres)

Crop	Total Irrigated Acreage	Surface Irrigation						Sprinkler Irrigation			Drip Irrigation	Sub Irrigation
		Wild Flood	Border	Basin	Furrow	Total	Solid Set	Hand Mov.	Mech. Move.	Total		
Alfalfa	497*	—	390	30	12	432	—	45	20	65	—	—
Pasture	544	85	370	—	—	455	8	73	8	89	—	—
Rice	142	—	65	77	—	142	—	—	—	—	—	—
Sugar beets	138	—	—	—	110	110	—	24	4	28	—	—
Misc. Field	1,226	—	441	—	603	1,044	—	130	12	142	—	40
Misc. Truck	372	—	—	—	300	300	40	28	4	72	—	—
Misc. Orchard	518	—	150	24	130	304	49	145	8	202	12	—
Vineyard	221	—	61	4	120	185	28	8	—	36	—	—
Statewide Totals	3,658	85	1,477	135	1,275	2,972	125	453	56	634	12	40
Percent by Method	100	2	41	4	35	82	3	12	2	17	—	1

*"Irrigation in California", Report to State Water Resources Control Board, June 1975, by J. Ian Stewart, Division of Agricultural Sciences, University of California, Davis.

Some types of well designed sprinkler systems can be adapted to most crops and soils. The primary reasons for the trend toward sprinkler systems are (1) increased profits resulting from favorable crop response (yield and quality); (2) savings of scarce, high-cost water; (3) reduced labor required for some types of sprinkler system; (4) good water control without leveling on problem areas, such as uneven surfaces, shallow or sandy textured soils, and land subject to subsidence; (5) better salinity control and plant germination; and (6) opportunities for multiuse of the system for both irrigation and frost control on certain permanent crops.

With these apparent advantages one might ask why sprinklers are used on less than 20 percent of the State's irrigated areas. Limitations responsible for this relatively small percentage are:

1. Reluctance or inability to assume the costs ($700 to $1,200 per acre; $1,700 to $3,000 per square hectometre) for labor-saving-type sprinkler systems.

2. Gravity systems already installed and performing reasonably well.

3. Extensive prior investments in gravity irrigation systems, such as for land leveling, and for other water and labor-saving features, e.g., lined ditches, structures, and pipelines.

4. Characteristics of certain crops, including crop height, flooding requirements of rice, and disease problems associated with sprinkler use under certain conditions.

5. Increased energy costs for the comparatively high operating pressures required for sprinklers.

In addition to the water saving that might result from conversion of gravity irrigation methods to sprinkler systems, additional savings would occur as some of the older hand-moved sprinkler systems are converted to permanent or various types of mechanically-moved systems, which generally operate more efficiently.

Drip Irrigation

In spite of limited research and experience with drip irrigation, an estimated 70,000 acres (30,000 square hectometres) are currently (1975) being irrigated by this method. However, this is actually less than 1 percent of the total irrigated acreage in California.

The drip method involves frequent low-volume applications of filtered water through devices called emitters. The emitters are spaced along field delivery lines to slowly supply water at various locations, depending on the particular crop and soil requirements. The application of water must be slow enough to prevent excessive accumulation on

Hand-moved sprinkler systems

the soil surface and to assure water movement below the soil surface into the root zone, mainly by capillarity (unsaturated movement). Each emitter typically discharges less than 1.5 gallons (5.7 litres) per hour and applies water at quite frequent intervals compared to other methods. The drip method maintains relatively high levels of soil moisture, in contrast to the greater soil-moisture depletion that typically occurs between irrigation application by other methods.

Recent widespread interest in drip irrigation has largely resulted from growers' desire to irrigate high-value crops with expensive water, often under conditions not suited for other irrigation methods. An outstanding example of such conditions is the use of drip irrigation in San Diego County, where avocados are grown on steep, rocky slopes, on which other irrigation methods could not be used without excessive runoff. About half of California's drip-irrigated acreage is in tree and vine crops in the southern San Joaquin Valley, where growers are interested in the opportunities to reduce irrigation costs — through reduced labor requirements and water savings.

The results of early experiments indicated that drip irrigation would result in increased yields with less than half the usual amount of water applied. However, in light of present knowledge, such generalizations must be viewed critically. Several years of field experience and applied research have demonstrated that actual water savings associated with drip irrigation vary widely and that the potential savings for each situation must be assessed separately.

Some of the advantages offered by drip irrigation are:

1. Drip irrigation results in substantial reductions in total evaporation from the soil surface in cases where only a limited area is wetted, such as when tree and vine crops are young and the root zone is relatively small. As full growth is reached and the root zone becomes larger, more emitters are required and a lesser savings can be expected.
2. Drip irrigation tends to eliminate runoff and deep-percolation losses.
3. Drip irrigation is ideally suited for steeply sloping lands.
4. With careful management, drip irrigation enables the use of lower quality water.

Some of the problems associated with the use of drip irrigation are:

1. Sediment, chemical, and biological clogging of the system.
2. Rodent damage.
3. Uncertainty of costs; initial costs range from $550 to $1,200 per acre ($1,400 to $3,000 per square hectometre); most drip systems were installed less than 3 years ago; what is the expected life of this equipment (particularly above-ground emitters and delivery lines)?

Drip irrigation of young pistachio trees

Permanent-set sprinklers — young almond trees interplanted with cotton

4. Management uncertainties; to what extent will field delivery lines interfere with such production practices as spraying, weed control and harvesting?

5. Salinity and ion toxicity uncertainties; irrigating with frequent or continuous application is well suited for diluting soil solution salt concentrations, but excessive periphery salt buildup in the root zone must be avoided.

6. Design uncertainties in converting existing irrigation systems to drip systems; how will established trees and vines with extensive root systems respond to limited soil volume irrigation application?

7. Problems associated with California's extensive low-water-intake-rate soils; even the low flow emitters presently being used result in surface flooding on many soils; more field and research experience is needed in automated recycling of applications to possibly adapt drip systems to soils with low intake rates.

8. Weed control in wetted areas.

Improving Existing Systems

Unavoidable on-farm water losses occur with all irrigation methods and systems. However, improvements in system design, operation, maintenance, and water management will help minimize those water losses over which the farmer has some control. Good system design is complicated, requiring not only skilled planning ability to carefully evaluate system alternatives but also a detailed knowledge of evapotranspiration (ET), crops, and soils. Each system must be custom-designed for a particular set of on-farm conditions.

Design features built into irrigation systems are usually expensive to change. Therefore, the designer must carefully consider peak ET and crop irrigation scheduling requirements, water quality, present and future water availability, possible fluctuations in supply, anticipated changes in future land use, and drainage provisions. He must also consider the selection of structures and materials, the availability of labor, safety provisions, and energy requirements, along with long-term cost-return considerations. All of this information must be integrated into a system design with water-saving features.

On the other hand, even with a well-designed system, some water loss is unavoidable. And, the best available system cannot compensate for poor scheduling decisions, inefficient operation, or improper maintenance.

Water savings from improved on-farm water management and system operation can be attained by:

1. Improved labor management and training.

2. Better follow-up of planners and designers in correcting operational mistakes.

3. An understanding of plant soil-water relations and crop irrigation practices, and the ability to identify and quantify farm water losses.

4. Water flow and soil-water measurements to help identify the source and extent of water losses.

5. Replacement of open earth ditches (used in gravity irrigation) with lined ditches, modern control structures, and pipelines.

6. Well prepared land, particularly with gravity irrigation.

7. Improvement of existing systems.

On-Farm Reuse Systems

This discussion of water reuse systems is specifically concerned with on-farm capture and reuse of *tailwater,* i.e., runoff resulting from irrigated agriculture. In a typical on-farm reuse system, small sumps at the lower end of an irrigated field collect surplus applied water, which is pumped to a head ditch and reapplied.

Some runoff is unavoidable with any gravity irrigation method on land with some slope and it is not necessarily a result of poor on-farm practices. The extent of on-farm runoff varies widely; the average is estimated to be between 10 and 15 percent of farm-applied water. At present, on-farm tailwater recovery systems are used on less than 5 percent of the gravity-irrigated lands in California.

Although runoff is lost to the farmer who does not have on-farm reuse facilities (usually called tailwater recovery systems), it is partly recovered and reused within most irrigation districts or hydrologic basins. This was discussed in Chapter II and is further discussed in some detail in Chapter V.

Future water costs, availability, competing beneficial uses of water, and legal restraints could cause increased use of tailwater recovery and reuse systems. In some parts of California, water quality controls regulating total salts, nitrate levels, or the containment of plant and animal effluent wastes and various agricultural chemicals, have forced the adoption of tailwater recovery and other reuse systems to help attain environmental objectives. Future enforcement of water quality control standards could significantly increase the adoption of on-farm reuse systems in managing agricultural runoff.

Tailwater recovery systems offer some potential on-farm water savings. However, the savings should not be overestimated, because in many cases surface runoff from individual farms is already recovered and reused elsewhere within the hydrologic basin.

Limitations or disadvantages of reuse systems include (1) increased costs (lift pumps, pipelines, etc.); and (2) reduced runoff, which in turn, could decrease the water available for fish and wildlife, and the water used to maintain minimum flow requirements.

Irrigation Scheduling

To efficiently schedule his irrigation, a grower must understand climate, soils, crops, and complex management factors that influence irrigation scheduling decisions. If he misjudges any of these factors, he may irrigate too often or not often enough. A knowledge of water-use rates for various crops at various growth stages and localities is essential for scheduling irrigation in a manner that will minimize water losses. The following approaches will reduce water losses through improved irrigation scheduling practices.

1. Following irrigation scheduling guidelines for a particular crop, soil, and ET rates as recommended by irrigation specialists; the particular irrigation schedule to follow will depend on water costs, availability, and the level of desired crop response per unit volume of water.

2. Monitoring soil moisture depletion levels within the root zone as a guide to irrigation scheduling through use of tensiometers, resistance blocks, soil sampling tubes or soil augers.

3. Predicting soil-moisture depletion levels and irrigation needs by the soil-moisture budget method; this requires a daily accounting of ET and knowledge of rooting depths, water-holding capacities, desirable depletion levels before each irrigation, and farm irrigation efficiencies.

Improved irrigation scheduling has the potential to conserve water by producing higher crop yields and quality per unit volume of water applied. Water savings through improved scheduling may result from:

1. Less than "full" irrigation; experience has shown that with many crops, acceptable yields can be attained without maintaining consistently high levels of soil moisture, i.e., plants can be allowed to "suffer" or "stress" at certain stages of development. The relationship between yield and quantity of applied irrigation water is not well understood by many irrigators. Research findings typically show that yields rise from low to maximum levels with each incremental increase in irrigation water. After the maximum yield level is attained, additional increments of applied water will gradually cause an actual reduction in yield and perhaps quality.

2. Reducing soil surface evaporation by irrigating infrequently before a full cover condition exists.

3. Scheduling irrigation applications in a manner that will reduce runoff and deep percolation losses.

4. Maintaining flexibility in the operation and management of the irrigation system to allow for marked changes in soil infiltration rates that occur from one crop growing season to the next and even within a particular season.

5. Scheduling irrigation applications for maximum use of natural precipitation.

Good Drainage

The management of excess water, either surface or sub-surface, is a vital consideration for on-farm, district, and basinwide interests. Land leveling or smoothing should be based on both efficient application of irrigation water and management of excess surface water. In general, California farmers have done an outstanding job of land preparation, but further improvement can still be made to minimize standing water, which adversely affects about 5 percent of the State's irrigated acreage.

Subsurface drainage problems generally result from soils becoming saturated by perched or shallow water tables. Saturated subsoils damage crops by restricting soil aeration, increasing plant diseases, and increasing both on-farm and basin salt problems. More than 400,000 irrigated acres with such problems are now in production because of the installation of subsurface drainage systems.

About 75 percent of this acreage is presently in the Imperial Valley. Without provisions for subsurface drainage to control shallow water levels, more than half of the Imperial Irrigation District's irrigated lands would be nonproductive.

An increasing area on the west side of the San Joaquin Valley is also adversely affected. Again, more than 70,000 acres (28,000 square hectometres) of these lands are now productive because of the installation of subsurface drainage systems. By the year 2000, 1,000,000 acres* (405,000 square hectometres) of San Joaquin Valley irrigated lands will require some control of shallow water tables. Moreover, production will be impaired on an estimated 75,000 acres (30,000 square hectometres) of irrigated land in other areas of California if tile drainage systems are not installed.

Improved surface and subsurface drainage results in:

1. Increased crop yields. Poor field drainage conditions reduce per-acre yields. Inferior crop stands usually require as much water as good ones. Any practice, such as improved drainage, that results in higher yields could influence water savings by satisfying increasing food demands with less water per unit of yield.

2. Improved soil-moisture salinity status in the sensitive root zone area of plants. As soluble salt levels increase in the soil root zone, less soil moisture becomes available to plants. More favorable soil salinity levels can often be maintained through improved drainage. With an improved soil-moisture salinity status, irrigation schedules that permit higher soil moisture deficits can be followed, i.e., less frequent irrigation.

3. Elimination of standing water within cropped areas. More refined land leveling and adequate surface water runoff facilities will prevent water ponding and crop damage.

On-farm surface and subsurface drainage provisions ultimately depend on irrigation district and basinwide management facilities. The need to manage surface runoff water from agricultural land is more readily recognized than is the off-farm management of subsurface drainage effluents. Although a substantial portion of agricultural runoff is reused, subsurface effluent from tile-drained systems is generally of poor quality and presents a more complex disposal problem.

Preparing land for irrigation

*Bulletin No. 127-74, "Status of San Joaquin Valley Drainage Problems". December 1974. p. 25.

Inadequate preparation of this land resulted in loss of forage due to growth of phreatophytes in areas of standing water

Salt Management

Salinity is one of agriculture's most complex production problems. If excessive salts from irrigation water or high water tables are permitted to accumulate in the soil, crop production is adversely affected; if no remedial measures are taken, economic crop production will eventually become impossible.

Salt levels are more difficult to control in soils with poor internal drainage than on well-drained soils. In addition, crops have different salt tolerances. The proportion of applied irrigation water required to maintain acceptable soil moisture salinity will therefore vary with different crops, different irrigation waters, and acceptable crop losses. Present guidelines for interpretation of water quality and leaching requirements are available in local Farm Advisors' offices.

Agricultural experts do not completely agree on what constitutes an adequate leaching water requirement. Since 1911, various water quality guidelines have been developed and periodically modified with new information. The present guidelines in California, which were developed at the U.S. Salinity Laboratory, incorporate new concepts developed primarily through lysimeter studies. These concepts are based on the premise that salinity level in the lower portion of the root zone can be maintained at relatively high levels as long as salt levels in the major root zone are not excessive.

The guidelines are not perfect and will be further modified on the basis of additional research and field experience. The new guidelines have particular significance for on-farm water savings, because the lysimeter tests indicate that less applied water is necessary to satisfy the leaching requirement than was previously recommended. The tests also indicate that if the minimum leaching concept is practiced, less salt will percolate into ground waters.

The conservation of water through following a minimum leaching plan would require a rather sophisticated level of on-farm water management not practiced by most farmers. Irrigation systems would have to be capable of high uniformity of application. The irrigator would need to follow very exacting schedules. These could require soil-moisture instrumentation and monitoring of salinity levels in various portions of the crop root zone.

Actually, a majority of farmers are already inadvertently practicing minimum leaching because of the preponderance of soils with low intake rates.

In such soils, losses of water from deep percolation below the root zone are generally small.

Rainfall Utilization

Potential water saving from more effective use of rainfall on irrigated land varies widely with rainfall amounts, timing and intensities, soils, and cropping patterns. Obviously, rainfall is not important in the Imperial Valley, where less than 3 inches (76 millimetres) occurs annually. On the other hand, the importance of rainfall would vary greatly throughout the Central Valley, where the annual amounts vary from 5 inches (127 millimetres) south of Bakersfield to more than 38 inches (970 millimetres) north of Redding.

Management decisions affecting the efficient use of rainfall on irrigated land depend on:

1. The availability of soil-moisture storage capacity when precipitation occurs.

2. Scheduling irrigation applications so that maximum leaching benefits can be derived from rainfall.

3. Selecting planting dates and following growing practices that will enable effective use of rainfall stored in the soil.

In areas where a significant contribution of soil moisture can be expected from winter rainfall, soils are generally allowed to dry, as much as feasible, prior to crop maturity and harvest. This helps provide for maximum soil water storage capacity before winter rains begin.

Even under optimum conditions, only modest water savings could be expected through improved use of rainfall. There are very limited situations where it is possible to increase preseason soil moisture storage from present levels. For instance, infiltration of rainfall into the soil might be increased by improved land leveling, use of crop residues or plant cover, or by soil tillage.

Weed and Phreatophyte Control

Water losses by weeds in crops are highest in row crops, orchards, and grapes that have not attained more than 60 percent ground cover. Water is also lost when water-loving weeds (phreatophytes) are permitted to grow in open ditches or in poorly drained areas.

As part of normal maintenance, weeds and phreatophytes should be removed. Water losses to weeds and phreatophytes can be further reduced by lining ditches, replacing open ditches with pipelines, and draining areas where the water table is high.

Mechanically moved sprinkler system

On the other hand, weeds and phreatophytes provide food and cover for birds and other wildlife. Removal of this vegetation will reduce wildlife populations that depend on it for their existence.

Seepage Control

About 10 percent of the water diverted for agricultural use is lost to seepage from on-farm head ditches and from district canals and laterals. Irrigation districts are aware of the need to reduce seepage and other maintenance problems associated with open, unlined canals, and many districts have long-term plans for lining them.

New irrigation districts, or those rehabilitating out-dated facilities, tend to eliminate open ditches by installing closed-pipeline water-conveyance systems. The following must be considered in determining the economic feasibility of lining canals or using pipeline systems:

1. The cost of water losses to landowners within a project. Do water shortages occur during the growing season?

2. The extent and cost of seepage damage resulting from waterlogged areas. (Some waterlogged areas are outstanding wildlife habitat.)

3. The project facility costs associated with higher diversion requirements to compensate for seepage losses, and high maintenance costs of unlined canals.

4. The reduction in ground water recharge that will result from canal lining or pipelines.

On about 4.1 million acres (1.7 million square hectometres) of the State's 7.4 million (3 million square hectometres) surface-irrigated acres, open, earthen ditches are used for on-farm water conveyance and distribution. On the remaining 3.3 million acres (1.3 million square hectometres), concrete-lined ditches, low-head buried pipelines, or surface aluminum lines, are used.

Farmers are becoming increasingly aware of the water saving and other advantages of eliminating earthen ditches. This practice not only reduces seepage and evaporation losses along the ditches, but also reduces labor and system maintenance. Pipelines also require less land area than canals and produce more positive control in water management. More permanent on-farm conveyance and distribution facilities can probably be justified on at least half of the 4.1 million acres (1.7 million square hectometres) on which earthen ditches are presently used.

On the other hand, on-farm reservoirs are not a source of significant water losses. Such reservoirs are used mainly for frost-control storage and, to a lesser extent, for storage for low-yield wells.

Because of their relatively low initial cost, chemical sealants and commercial bentonites are used in both small reservoirs and canals. Concrete lining offers the most permanent seepage control for reservoirs and canals. However, the cost ($8 to $10 per square yard) ($10 to $12 per square metre) is beyond the means of most farmers.

Evaporation and Transpiration Suppression

The control of evaporation and transpiration has some potential for water savings. Evapotranspiration (ET) can be reduced by "stressing" the plant, i.e., limiting soil moisture. The practice of limiting soil moisture under certain cropping conditions was discussed in a preceding section.* The feasibility of reducing water use by limiting soil moisture varies with (1) the crop, (2) the growth stage, (3) the farmer's ability to schedule and manage irrigation, and (4) the cost and availability of water.

Most field and vegetable crops have been shown to have quite similar daily ET after a full-cover condition has been attained (more than 55 percent ground cover). Prior to full-cover conditions, the level of ET is influenced largely by percent of ground cover and relative wetness of the soil surface. ET can be significantly reduced before full cover conditions exist by reducing soil surface wetness through (1) infrequent water applications and (2) use of irrigation methods or techniques that do not wet the entire soil surface.

Antitranspirants for reducing plant water losses are now being investigated. An antitranspirant is a chemical applied to the plant leaf surface to reduce transpiration either by inhibiting stomatal opening or through the effects of a physical barrier to retard the escape of water vapor from plants. Preliminary experimental work has shown that antitranspirants can substantially reduce transpiration but that they also reduce photosynthesis. Therefore, antitranspirants must be used with great care, so that reduced photosynthesis will not have adverse economic effects.

Another source of water loss is evaporation from free water surfaces. Losses from major water storage areas, such as lakes and reservoirs, vary from 3 to 5 feet (1 to 1.5 metres) annually in California, depending on the location.

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*See "Irrigation Scheduling," p. 48.

Spreading a thin film of chemicals on the water surface to reduce evaporation has received considerable testing. The most common monomolecular film tested is hexadeconol. Studies show that as long as the film remains intact, evaporation is measurably reduced. However, if the monomolecular layer is disrupted by winds, its effectiveness is destroyed. The films also adversely affect fish and other aquatic life.

Crop Factors

Seasonal water requirements could be reduced if crops were planted with water savings as a prime consideration. For example, water can be saved by planting short-season crops, which require less water than do those with longer growing seasons. Conservation goals could also be promoted by a long-range state policy to reduce the production of high water-using crops, such as forage or rice, and encouraging the production of cereal grains, which require less water.

The length of growing season varies among varieties of a particular crop as well as among different crops. Selection of a crop that shortens maturity by only 1 week could reduce seasonal ET by about 2 inches (50 millimetres).

In the same vein, deep-rooted crops require less-frequent irrigation than do shallow-rooted crops. Reduced irrigation frequency generally results in less surface runoff and reduced losses to deep percolation.

If crops were selected on the basis of the factors discussed in this section, the potential water savings would appear to be significant. Farmers, however, generally select crops on the basis of market demand, which is not always compatible with water-saving objectives.

System Automation

At present, automatic water-control mechanisms, which regulate water levels in major canals and lateral systems, are in limited use in California. Such automatic systems can produce water savings through more accurate diversions and allocations of project water.

On-farm automatic systems include mechanisms that start and stop power units, and thus water flow, at predetermined times. Such controls help conserve water by preventing excessive water application. By contrast, manual systems might not be turned off at night or at other inconvenient hours.

Automatic water-level controls for open ditch on-farm irrigation systems are used very little today. Controls of this type and for closed systems are being developed through various research efforts now underway. The use of automated on-

Wild flooding is a very inefficient irrigation method

farm water-control systems could increase surface irrigation efficiency by reducing reliance on the often-variable human performance.

Automation has also enabled cyclic, short-period water applications, which show promise for both reducing surface runoff and increasing the depths of moisture penetration in soils with low intake rates.

Automated irrigation systems are presently too expensive for most on-farm situations. However, as irrigators find it necessary to replace older manual systems, the increased use of automated systems can be expected.

Land Use

Water conservation is also related to the efficient use of croplands. Selecting crops on the bases of soil and slope conditions increases the potential for high irrigation efficiency and high crop yields.

Planting the wrong crops on marginal land often results in wasted water. For example, water could be wasted by attempts to produce permanent tree or vine crops on shallow, stratified soils or on soils with high water tables. Other examples are (1) rice planted in highly permeable soil, which would result in excessive percolation losses of the ponded water, and (2) salt-sensitive crops planted in saline soils.

Institutional

In the preceding sections, measures for reducing water use at the place of use, i.e., on the farm, were discussed. This section presents a brief discussion of the roles of the Federal and State Governments and local water districts in conserving water.

The U.S. Bureau of Reclamation (USBR) has an irrigation management services program to assist in increasing irrigation efficiencies in the districts they serve. This program consists of trial projects, which demonstrate methods for scheduling irrigation, based on daily evapotranspiration, soil moisture holding characteristics, and specific crop water needs. Once the system has been satisfactorily demonstrated, the water district is encouraged to take over the operations. The program has been conducted in only a few districts to date. It should be expanded to all USBR water service areas.

The U.S. Department of Agriculture Soil Conservation Service has provided similar services in other states. It should be encouraged to conduct such programs in California.

At the state level, the University of California Cooperative Extension Service should be encouraged to expand its irrigation advisory services as well as irrigation-related research.

The State Water Resources Control Board and the regional boards have authority relating to the control of waste discharges. The quantity and quality of waste discharge are dependent on the nature and manner of water use. Future controls over waste discharges expected to be mandated under the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) and the state Porter-Cologne Water Quality Control Act will undoubtedly affect irrigation efficiency. In addition, the Water Resources Control Board has the authority to set terms and conditions regarding the use of water when acting upon applications to appropriate water.

The Department of Water Resources will take a lead role in promoting water conservation. The Department's support of any proposed water management action, whether local or federal, will be contingent upon the inclusion of an effective water conservation element wherever appropriate. The Department will vigorously pursue a program of identification of water waste and work with other agencies toward elimination of such waste. Legislation will be sought to provide added legal and institutional means for accomplishing water conservation.

Basin irrigation

Legislation is also needed to clarify the authority of local irrigation districts to require water conservation practices. Their delivery systems and delivery schedules should be modified wherever changes would facilitate implementation of conservation practices by farmers.

In addition, all agencies with responsibility for water management should work together in developing coordinated systems and operation procedures that will (1) enable greater underground storage of surplus winter runoff through conjunctive use of surface and ground water; (2) improve the process of delivery of water and the capture and allocation of return flows; (3) reduce overall energy use; and (4) enable expansion of beneficial uses of the developed water supply, including improved instream uses. The hydrologic characteristics of the State require a high degree of coordination between all agencies involved.

Pricing of Agricultural Water

Ideally, water-pricing systems should have three objectives: (1) return sufficient revenue to cover the cost of the water; (2) be equitable, and (3) discourage waste. The first is attained in various, often complex, ways in most cases today and sometimes involve subsidies to the agricultural water user. One example of this is the pricing policy of the U.S. Bureau of Reclamation.

Furrow irrigation

The cost of water development and delivery by the Bureau is met by charges to the agricultural users, power sales, municipal water sales, federal and nonfederal payment of costs allocated to recreation and fish and wildlife, and federal payment of cost for flood control features. Both the power and the municipal water are priced at levels which produce revenues that are used to reduce the cost of water to the agricultural users. The elimination of interest charges for the portion of the cost allocated to agriculture further reduces the price of water.

The pricing policies of the Bureau are being reviewed by various interests, including the Bureau itself. Questions of equity and public policy are involved.

Reduced water price rates for agriculture (i.e., subsidies) are not unusual in California among local water agencies that deliver both urban and agricultural water. Here, too, public policies regarding social and economic objectives are involved. In determining the feasibility and desirability of revising pricing systems to promote water conservation, the likely social and economic impacts should be carefully identified and assessed in terms of current public policy.

In the cases of subsidies, water prices might be changed to the extent that farmers pay the full cost of developing and delivering the supply. However, many agricultural water users already are paying the full cost. These include ground water users and members of agricultural water districts that have developed their own surface supplies.

In the case of local districts which have already paid for their major facilities, or for other reasons have only minimal financial obligations, the price of water to users is extremely low. The legal basis for increasing water price to the extent that total revenue exceeds the cost of providing the water has not been established.

In the case of some ground water users, it may be argued that their supply exists, in part at least, as a result of percolation of excess applied water originating from surface water developments paid for by others. Again, the legal basis for charging for extraction and use of this water has not been established.

Impacts of Increasing Water Price. Increasing water price could result in reductions of water use if farmers change their irrigation systems and practices or change to lower water-using crops. Opportunities to do the latter depend on the availability of markets for these crops.

The increased cost of the water and the cost of the improvements needed to reduce water use might be offset, at least partially, by various benefits associated with better water management. These might include: increased returns due to better quality crops and increased yields; reduced costs for fertilizers, herbicides, energy, and labor; reduced loss due to disease; and reduced cost of disposing of tailwater.

There are other possible impacts of increasing water price that must also be considered, however.

In most areas, water charges would have to be increased substantially to effectively induce the majority of farmers to undertake water conservation practices. Without allowances being made for the wide variations in farm crop production and marketing characteristics, some farmers may be forced out of business; in most cases, these would be the smaller farmers, who typically, have the least operational and financial flexibility.

Those farmers with sufficient flexibility might not make changes to improve irrigation efficiency, but rather may change to higher income crops to the extent that market conditions allow such changes, or they may make other operational changes to offset the increase in water cost.

Although these and other possible impacts, such as the effect on market competition, production of low payment feed and forage crops required by livestock and dairy production, and food prices must be considered, the need to conserve water requires that all means for effecting increased water use efficiency be examined and implemented where reasonable.

CHAPTER V.
OVERALL ASSESSMENT OF POTENTIAL AGRICULTURAL WATER CONSERVATION

In Chapter IV, various methods of reducing farm applied water requirements were discussed. Chapter V provides (1) a discussion of conservation measures that appear to be most applicable to each of California's 11 hydrologic study areas (HSA's) and (2) general estimates of the quantities of water that might be saved — within each HSA and on a statewide basis. Also discussed are the probable effects of conservation measures on energy consumption, streamflow, recreation, and fish and wildlife.

The determination of overall water savings that could result from increased farm irrigation efficiency requires examination of the total effects within each HSA, considering such factors as ground water recharge and withdrawal, water quality changes, in-basin reuse, and water use for fish, wildlife, and recreation. This broader approach considers the overall use of water by all irrigators in an HSA and accounts for reuse of water within a hydrologic system.

Because of the substantial quantities of water reused in most parts of the State, overall basinwide water savings resulting from improved irrigation practices might be lower than expected. However, in most areas, water conservation measures could help attain additional objectives, such as (1) improved in-stream water use, (2) increased conjunctive use of surface and ground water to enable greater underground storage of surplus water, and (3) energy savings. Identification of specific opportunities to attain these objectives would require detailed studies that are beyond the scope of this report. Chapter V, however, does provide a basis for selecting areas where more definitive studies of these objectives might be conducted.

As discussed in Chapter II, reused water may comprise a substantial portion of farm applied water supplies. The water reused is obtained partly from surface drains or streams, while the remainder, which originated as percolate from canals, farm distribution systems, and excessive irrigation, is pumped from underground.

These percolating waters comprise part of the estimated safe yield of any ground water basin. In some HSAs, greater efficiency of farm-applied water use would result in both (1) decreased demands on surface and/or ground water supplies, and (2) reductions in surface drainage flows and ground water recharge.

As used in this bulletin, hydrologic-study-area efficiency is defined as the evapotranspiration of applied water (ETAW) divided by net basin demand, expressed as a percentage. Net basin demand is the quantity of water needed to meet ETAW plus all other irrecoverable losses incidental to irrigation, plus reusable return flows leaving the basin.

Because large quantities of irrigation water may be reused within a basin, total farm-applied water, as measured at farm headgates, is usually much larger than net basin demand. For example, 1 million acre-feet (1233 cubic hectometres) might be applied in a given service area, but this total may comprise 700,000 acre-feet (863 cubic hectometres) of delivered water plus 300,000 acre-feet (370 cubic hectometres) of reuse. On the other hand, in certain areas, such as the Colorado Desert HSA, where reuse is limited by the highly saline return flows and where conveyance losses are high, net basin demands may exceed total applied water.

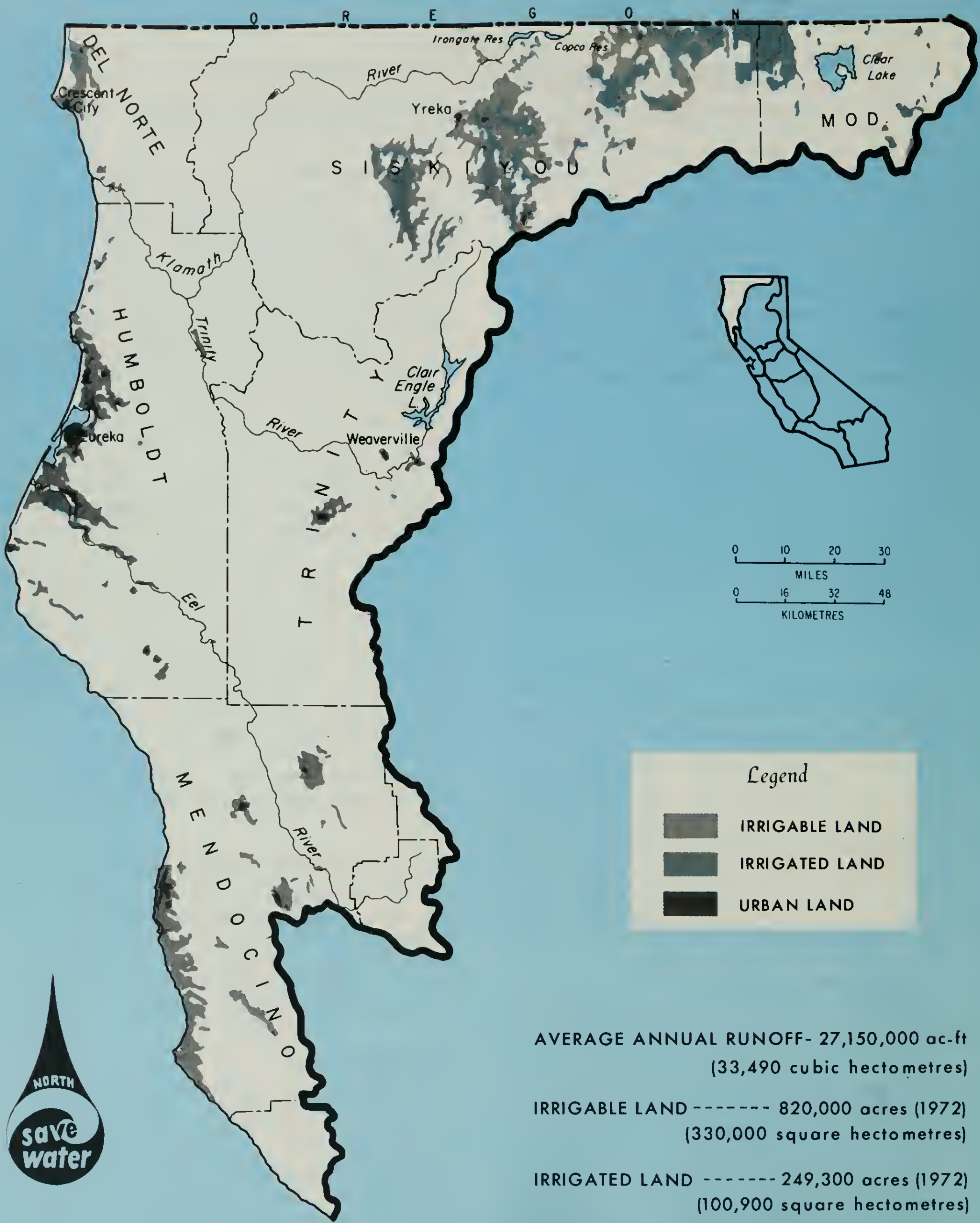
The following discussions of each HSA (1) describe the hydrologic characteristics that influence water-use efficiency, and (2) assess the impacts of various water conservation measures that might be implemented. Chapter V concludes with a statewide summary, which suggests possible changes in HSA efficiency that might be attained, and estimates the quantities of water that might be saved.

North Coastal Hydrologic Study Area

The North Coastal HSA, a large mountainous, generally wet region, contributes 40 percent of the state's runoff, but contains very little irrigated agriculture. The 250,000 acres (100,000 square hectometres) presently irrigated are found primarily in a few moderately large valleys (Figure 8).

Irrigated Agriculture

Agricultural areas dependent mainly on stream runoff, such as those in Scott and Shasta Valleys, are faced with greatly reduced supplies during the late summer months. Butte Valley in eastern Siskiyou County, however, obtains the major portion of its supply from ground water. Ground water has been developed to some extent in all of the major valleys within the North Coastal HSA.



AVERAGE ANNUAL RUNOFF- 27,150,000 ac-ft
(33,490 cubic hectometres)

IRRIGABLE LAND ------- 820,000 acres (1972)
(330,000 square hectometres)

IRRIGATED LAND ------- 249,300 acres (1972)
(100,900 square hectometres)

URBAN LANDS -------- 52,100 acres (1972)
(21,100 square hectometres)

FIGURE 8

NORTH COASTAL HYDROLOGIC STUDY AREA

Although much of the land on the coastal floodplains of the Eel, Mad, and Smith Rivers has been extensively developed in pasture for dairy and beef cattle, irrigated agriculture has been slow to develop. Thick summer fog and heavy winter cloud cover act as suppressants to evapotranspiration (ET) and the need for irrigation.

Irrigated land in the HSA is used mainly to provide forage for cattle production (see Table 12). Over 60 percent is used for meadow pasture, improved pasture, or alfalfa.

Table 12 indicates that the HSA currently has an overall basin efficiency of 74 percent. By almost all standards this would be considered highly acceptable. However, close scrutiny reveals that under actual field conditions, water use efficiency is very low during the spring months, when supplies are far in excess of demand, and then becomes very high by early July when streams begin to dry up and water is short. The combination of these two conditions must be understood to properly evaluate a seemingly high overall seasonal efficiency.

Economic Pressures

During the past decade, the general price-cost squeeze experienced by agriculture throughout the nation has produced a change in an economy previously turned to the husbandry of beef cattle on meadow pasture. Cattlemen are now being forced to produce more pounds of beef per acre. This is being accomplished through a series of irrigation improvements: Land is being leveled and irrigated by sprinklers to get better seed germination and uniform water application, the use of ground water to extend irrigation into the late summer months is increasing, and land previously planted to meadow pasture are giving way to higher-producing crops such as field corn. The costs of improvements, however, are high and progress is slow.

Consequences of Improved Irrigation Practices

Water used for irrigation in the North Coastal HSA is currently not subject to appropriation outside the geographical area. The water is needed in the valleys in which it occurs to increase the irrigated acreage base, improve flows for anadromous fish species, and enhance the environment for fish and wildlife.

Table 13 lists some of the positive actions that can be taken to improve on-farm and basin water use efficiency. The more outstanding of these are land leveling, the lining of permeable irrigation ditches, and the abandonment of irrigation on marginal lands.

Ditch lining could enhance fish flow in the tributary streams by reducing the amount of water diverted. Moreover, water historically diverted but lost to seepage could be used to increase the acreage under irrigation. On the other hand, ditch lining can also dry up the water-loving vegetation required for the survival of wildlife.

TABLE 12

AGRICULTURAL LAND AND WATER USE
NORTH COASTAL HYDROLOGIC STUDY AREA
1972

Irrigated lands	Area		Average unit applied water		Range in unit applied water		Applied water	
	1,000 acres	square hectometres	feet	millimetres	feet	millimetres	1,000 acre-feet	cubic hectometres
Miscellaneous Field	4.5	1,800	2.2	670	1.7-2.5	520- 760	10	12
Alfalfa	45.4	18,400	3.7	1,150	1.5-4.2	460-1,300	169	208
Pasture	74.5	30,100	3.5	1,100	1.7-4.7	520-1,400	261	321
Meadow Pasture	32.0	13,000	1.9	580	1.9-3.0	580- 910	61	75
Miscellaneous Truck	19.2	7,770	3.1	950	1.0-3.2	300- 980	59	73
Deciduous Orchard	1.0	400	2.0	610	1.4-2.0	430- 610	2	2
Grain	72.7	29,400	2.0	610	0.9-2.0	270- 610	145	179
Totals	249.3	100,870					707	870

Evapotranspiration of applied water (ETAW) = 441,000 acre-feet (544 cubic hectometres)
Net basin demand = 595,000 acre-feet (734 cubic hectometres)

Hydrologic area efficiency = $\left(\frac{\text{ETAW}}{\text{net basin demand}}\right) = 74\%$

TABLE 13

NORTH COASTAL AND NORTH LAHONTAN HYDROLOGIC STUDY AREAS PRACTICES TO INCREASE THE EFFECTIVENESS OF AGRICULTURAL WATER USE

Practice	Agricultural Viewpoint		Fish-Wildlife-Recreation Viewpoint		Comments
	Positive	Negative	Positive	Negative	
Ditch lining	Water savings.	Expensive, possibly prohibitive costwise	Improved flows for anadromous fish in tributary streams.	Loss of phreatophitic marsh vegetation.	Practice should be financially supported by those benefiting. Practice applies mainly to Shasta-Scott Valleys.
Abandon irrigation on marginal land	Bring higher return lands under irrigation; higher production; higher income.	Prohibited by present water right laws.	See above.	Reduce marsh vegetation; might reduce return flows and, hence, fish flows.	Constrained by water rights. Practice applies mainly to Shasta-Scott Valleys.
Sprinkler irrigation	Water savings; increased productivity.	Costly; big power user.	Lower impairment of streams; increases in fish flows.	May reduce fish flows if more lands are irrigated.	Applicable to all north coastal agricultural areas.
Conjunctive use of surface and ground water	Better utilization of annual water supply; more land in production.	Increased power use; costly.	None	May reduce wetlands and fish flows through increased percolation of stream flow.	Butte and Scott Valleys may currently be approaching limit of available ground water.
Drainage canals and relift pumps	See above.	Annual maintenance cost; increased power costs.	None	Would reduce wetland habitat; could reduce fish flows.	Applicable mainly to interior mountain valley areas.
Land leveling	Higher irrigation efficiency, lower use, higher production.	Costly; loss of production for a year.	None	Would reduce wetland habitat.	May be applicable only to a limited acreage due to flood hazard, soil depth or slope limit.
Small rim stream reservoirs for additional storage	Store water for late summer irrigation.	Possible loss of irrigable land in reservoir site; may not be economically feasible.	Additional reservoir fishery; could create a live stream and shoreline rec.	Loss of habitat in reservoir area.	Funded by local recipients and all levels of government.

One of the major factors frustrating any attempt to salvage water is that water is not worth much in terms of crops produced in north coastal climate zones, whereas the costs involved in saving water are high. Attempts to alter the historic uses of water in California's north coastal mountain valleys must be carefully weighed in terms of these effects on both agriculture and the environment.

San Francisco Bay Hydrologic Study Area

Agriculture in the San Francisco Bay HSA occurs in four major subareas: the lower and upper Russian River Valley, the Sonoma-Napa Valleys, the Fairfield area in the North Bay, and the Santa Clara Valley in the South Bay. However, urbanization has all but replaced agriculture in the Santa Clara Valley and is a threat to agriculture in each of the other areas (Figure 9).

With the exception of the upper Russian River Valley, most North Bay agriculture has historically been rain-fed. Because of the cool maritime climate and moderately high rainfall, early settlers had no need for irrigation. Over the past two decades, irrigation has been on the increase, particularly as a means of obtaining higher yields from previously dry-farmed varietal grapes and prunes.

In the North Bay Area, irrigated agriculture is dependent upon both ground water and surface water sources. The surface water supply comes from several local projects: Lake Mendocino on the East Fork of the Russian River, Lake Berryessa on Putah Creek, and diversion from the Eel River through the Potter Valley Tunnel, which supplies the increasing irrigation needs along the Russian River.

In the South Bay Area, the source of irrigation water is largely ground water. The remainder is supplied by the South Bay Aqueduct. Prior to completion of the South Bay Aqueduct in 1962,

AVERAGE ANNUAL RUNOFF - 2,990,000 ac-ft
(3,690 cubic hectometres)

IRRIGABLE LAND - 700,000 acres (1972)
(300,000 square hectometres)

IRRIGATED LAND - 105,000 acres (1972)
(42,500 square hectometres)

URBAN LAND - 485,000 acres (1972)
(196,000 square hectometres)

Legend

IRRIGABLE LAND

IRRIGATED LAND

URBAN LAND

NORTH save water

FIGURE 9
SAN FRANCISCO BAY HYDROLOGIC STUDY AREA

salt water intrusion and land subsidence were a major concern in the Santa Clara Valley. Subsidence and long-term overdraft problems have been largely solved with this new importation.

Hydrologic area efficiency (see Table 14) is currently about 70 percent, and there is potential for reuse of deep percolation and runoff throughout the hydrologic study area. About 4,000 acre-feet (5 cubic hectometres) of reclaimed waste water is used annually. Increased waste water reclamation could provide significant additional water supplies for agriculture. However, the use of reclaimed waste water to meet summer irrigation or spring frost control demands for vineyards or orchards, the Bay Area's principal economic crops, has not been accepted by some irrigators.

The long-term effect of the use of reclaimed water on salt-sensitive crops must be studied. Meanwhile, the result of experiments using drip irrigation with reclaimed waste water in Southern California have been favorable so far. The availability of new water supplies through waste water reclamation could enhance and stabilize the wine industry in the Bay Area.

Because of the relatively small irrigated acreage, agricultural water-conservation practices are not expected to save much water in the San Francisco Bay HSA. Moreover, today's farmers tend to under-irrigate in some areas. In such cases, water applications fail to meet the seasonal ET demand of the crop. Thus, high farm applied water use efficiency becomes the norm.

TABLE 14

AGRICULTURAL LAND AND WATER USE
SAN FRANCISCO BAY HYDROLOGIC STUDY AREA
1972

Irrigated lands	Area: 1,000 acres	Area: square hectometres	Average unit applied water: feet	Average unit applied water: millimetres	Applied water: 1,000 acre-feet	Applied water: cubic hectometres
Miscellaneous Field	3.1	1,300	1.8	550	6	7
Alfalfa	1.8	730	2.2	670	4	5
Pasture	26.1	10,600	3.4	1,000	90	110
Miscellaneous	15.6	6,310	2.5	760	39	48
Deciduous Orchard	37.5	15,200	2.4	730	89	110
Vineyard	21.0	8,500	1.0	300	21	26
Total	105.1	42,640			249	306

Evapotranspiration of applied water (ETAW) = 172,000 acre-feet (212 cubic hectometres)
Net basin demand = 245,000 acre-feet (302 cubic hectometres)

Hydrologic area efficiency = $\left(\frac{\text{ETAW}}{\text{net basin demand}} \times 100\right) = 70\%$

Central Coastal Hydrologic Study Area

The Central Coastal HSA includes the drainage areas of the small coastal streams found on the Central California Coast between Santa Barbara on the south and Santa Cruz on the north (Figure 10). The terrain is typified by a series of small coastal valleys with cool maritime climates in the southerly portion. In the north, the Salinas and Pajaro Valleys are much larger and the climate ranges from a cool coastal fog-belt type to a typical hot interior-valley type. This range in climate, and particularly the frost-free winters, enables production of a wide range of crops in the Central Coastal hydrologic study area.

Present Agricultural Water Use

Ground water, much of which is supplied to downstream aquifers from storage reservoirs higher in the watersheds, is used for almost all irrigation in the hydrologic study area. In almost every coastal valley ground water pumping has permitted the intrusion of sea water, requiring that a careful balance of extraction and percolation be maintained.

AVERAGE ANNUAL RUNOFF - 2,450,000 ac-ft
(3,020 cubic hectometres)

IRRIGABLE LAND - 1,490,000 acres (1972)
(603,000 square hectometres)

IRRIGATED LAND - 450,000 acres (1972)
(180,000 square hectometres)

URBAN LAND - 140,000 acres (1972)
(57,000 square hectometres)

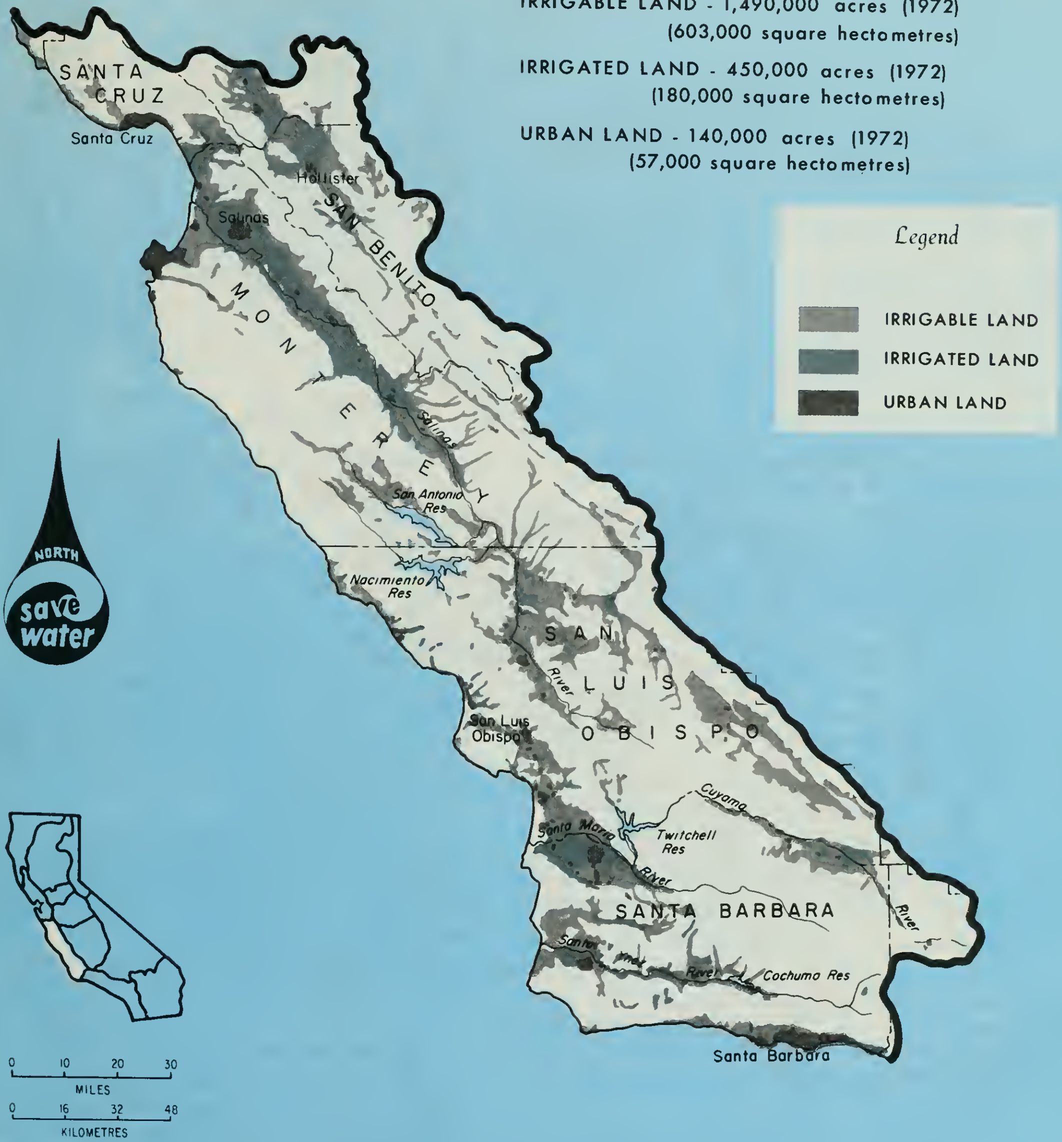


FIGURE 10
CENTRAL COASTAL HYDROLOGIC STUDY AREA

TABLE 15

AGRICULTURAL LAND AND WATER USE
CENTRAL COASTAL HYDROLOGIC STUDY AREA
1972

Irrigated Lands	Area		Average unit applied water		Range in unit applied water		Applied water	
	1,000 acres*	square hectometres	feet	millimetres	feet	millimetres	1,000 acre-feet	cubic hectometres
Miscellaneous Field	33.7	13,600	2.0	600	1.4-2.6	430-790	67	83
Sugar Beets	31.4	12,700	3.1	940	—		100	123
Alfalfa	38.0	15,400	3.4	1,000	3.3-6.4	1,000-1,950	128	154
Pasture	31.5	12,800	3.6	1,100	3.4-6.4	1,050-1,950	113	139
Miscellaneous Truck	221.9	89,800	1.9	580	1.6-2.5	490-760	422	521
Tomatoes	14.4	5,830	2.5	760	—		36	44
Deciduous Orchard	42.9	17,400	2.5	760	2.1-3.1	640-940	109	134
Subtropical Orchard	10.8	4,370	2.0	600	2.0-2.3	610-700	22	27
Vineyard	20.2	8,170	1.3	400	1.0-1.4	300-430	27	33
Grain	4.3	1,700	0.3	90	—		1	1
Totals	449.1	181,770					1,025	1,259

*Includes double cropping.

Evapotranspiration of applied water (ETAW) = 644,000 acre-feet (794 cubic hectometres)

Net basin demand = 780,000 acre-feet (962 cubic hectometres)

Hydrologic area efficiency = $(\frac{\text{ETAW}}{\text{net basin demand}} \times 100) = 83\%$

Table 15 shows that almost 450,000 acres (182,000 square hectometres) are irrigated annually. The overall hydrologic area efficiency averages 83 percent; this probably is true of small and large valley areas alike. Today, about 45 percent of the lands are irrigated by sprinklers and the remainder by careful furrow irrigation. Drip irrigation is just beginning to get a foothold; citrus in Santa Barbara County and vineyards in Santa Barbara and San Luis Obispo Counties are now drip-irrigated.

With salt balances and sea-water intrusion as possible problems facing this area of high water use efficiency, an increase in efficiency could actually have serious detriments. Therefore, water saving impacts must be examined on a case-by-case basis.

Opportunities for Water Savings

Some of the more sophisticated measures that reduce water use, such as drip or low-head sprinklers, are suggested. The use of more sprinkler irrigation could also increase the efficiency of applied water use somewhat. These are about the only measures that farmers might take to increase efficiency.

Additional off-farm measures to improve water use efficiency should be employed. Institutional arrangements that totally manage the water within entire ground water basins and watersheds should be encouraged. At present, several outstanding examples are in evidence. The construction of Nacimiento and San Antonio Dams by Monterey County Flood Control and Water Conservation District, to better regulate the Salinas River flows, has resulted in the stabilization of the Salinas Valley ground water basin. The proposed Castroville Irrigation Project, which would divert water from the Salinas River and transport it to the Castroville area to replace ground water pumping, will save water because it should prevent further sea-water intrusion in that area.

Pumping regulations of the Santa Clara Valley Water District also promote water savings. Off-farm measures might also include the removal of phreatophytic vegetation, which impairs ground water recharge in many areas. Removal of this vegetation, however, would also mean the loss of wetland habitat vital to the survival of many wildlife species.

South Coastal Hydrologic Study Area

The South Coastal HSA encompasses all of coastal Ventura, Los Angeles, San Bernardino, Riverside, Orange, and San Diego Counties. This 7-million-acre (3-million square hectometre) area has a relatively uniform climate along the coast with greater variations as the distance from the moderating effect of the ocean increases.

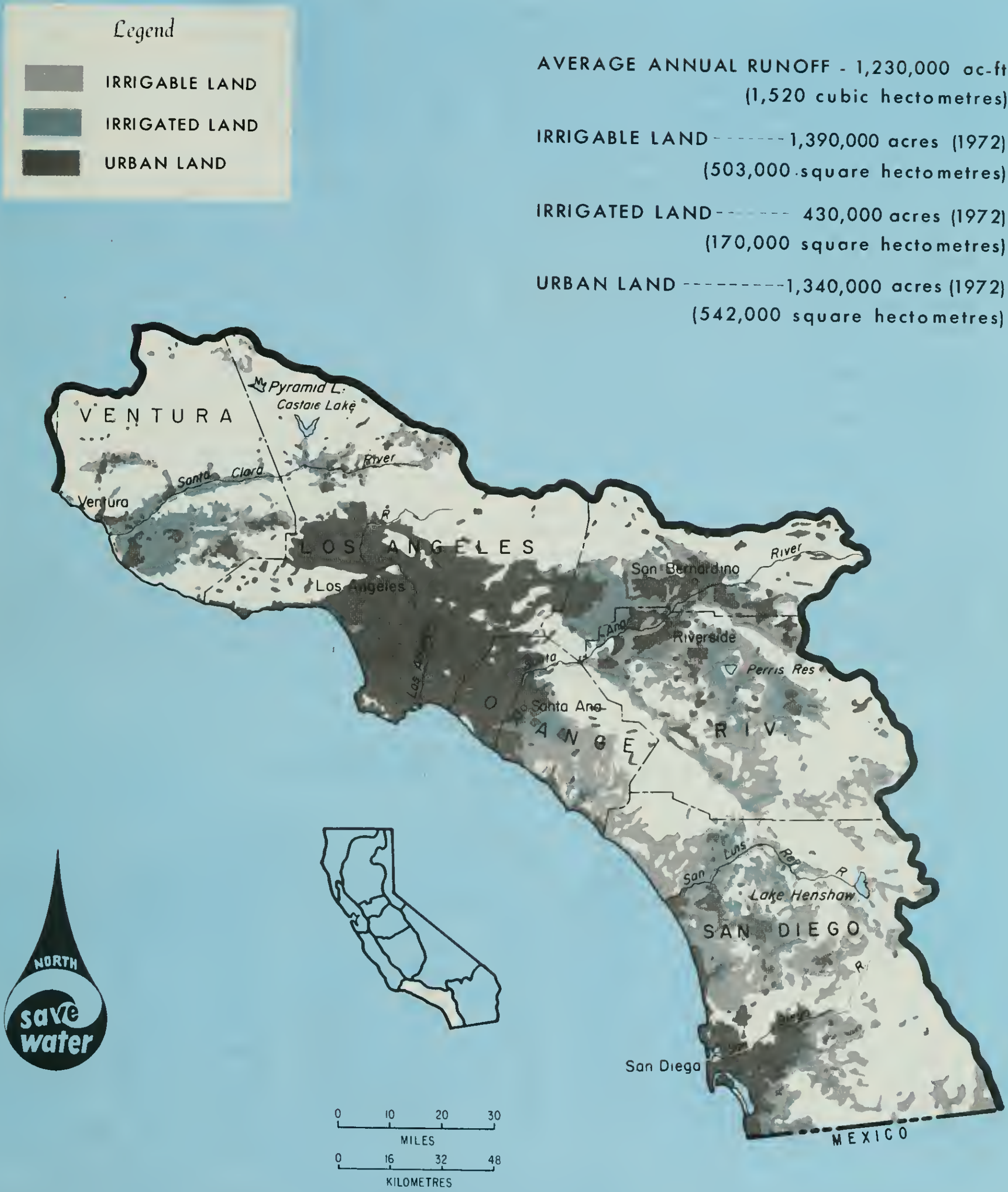


FIGURE 11
SOUTH COASTAL HYDROLOGIC STUDY AREA

Precipitation ranges from 12 to 16 inches (300 to 400 millimetres) on valley lands along the coast, increasing with elevation. Irrigation water is supplied from ground water supplies, local surface diversions, and supplies imported from the State Water Project, the Colorado River, and the Los Angeles Aqueduct. In many areas, water supplies are of moderately poor quality, particularly those imported from the Colorado River.

Irrigated Agriculture

The 430,000 acres (174,000 square hectometres) of irrigated agriculture comprise a broad range of crops (Table 16). The largest acreage is devoted to subtropical orchards, consisting mainly of citrus and avocados, and to various truck crops, such as strawberries, lettuce, and other vegetables adapted to the cool maritime climate. The main agricultural areas are the Oxnard Plain, Orange County, the Santa Ana River Basin, and San Diego County (Figure 11).

At present, about 200,000 acres (80,000 square hectometres) are irrigated by sprinkler systems and another 12,000 acres (5,000 square hectometres) by drip irrigation. The remainder, or about 50 percent is still irrigated by furrow or other conventional gravity methods.

Agriculture in the South Coastal HSA is probably the least permanent of any in California. Urban encroachment on agricultural lands continues at a rapid pace, leaving untouched only those lands in agricultural preserves or those designated as open space by local planning agencies. Agriculture will not completely disappear, but will eventually be limited to high-income crops as in San Diego County.

Opportunities For Water Saving

The high cost of water — more than $100 per acre-foot in some areas — is a real incentive for practicing water conservation. Drip irrigation systems have been extensively developed here, and a high degree of management is becoming more evident. Land will certainly be the limiting factor in the fate of agriculture, but water supply and price will also be major constraints.

A real future lies in the economic use of reclaimed waste water for irrigation. Large metropolitan areas continue to produce vast quantities of sewage, part of which could be reclaimed. The limitations now are centered around heavy metals, viruses, and high concentrations of dissolved solids.

Decreased irrigation in certain coastal basins would reduce ground water recharge by irrigation water and may increase sea water intrusion. If irrigated agriculture continues to decline, alternative methods of assuring ground water recharge will be needed.

TABLE 16

AGRICULTURAL LAND AND WATER USE
SOUTH COASTAL HYDROLOGIC STUDY AREA
1972

	Area		Average unit applied water		Range in unit applied water		Applied water	
Irrigated lands	1,000 acres	square hectometres	feet	millimetres	feet	millimetres	1,000 acre-feet	cubic hectometres
Miscellaneous Field	26.5	10,700	2.2	670	1.1-3.3	340-1,000	58	72
Sugar Beets	8.8	3,600	3.1	940	—		27	33
Alfalfa	20.3	8,220	3.9	1,200	—		79	97
Pasture	37.7	15,300	4.1	1,250	—		153	189
Miscellaneous Truck	97.6	39,500	2.0	600	1.6-3.2	490-980	197	243
Tomatoes	14.2	5,750	2.5	760	—		35	43
Deciduous Orchard	8.6	3,500	2.7	820	1.9-2.7	580-820	23	28
Subtropical Orchard	157.3	63,660	2.0	610	1.0-5.4	300-1,650	319	393
Vineyard	15.6	6,310	1.4	430	0.9-2.1	270-640	22	27
Grain	44.7	18,100	0.2	60	—		9	11
Total	431.3	174,640					922	1,136

Evapotranspiration of applied water (ETAW) = 646,000 acre-feet (797 cubic hectometres)
Net basin demand = 760,000 acre-feet (937 cubic hectometres)

Hydrologic area efficiency = $\left(\frac{\text{ETAW}}{\text{net basin demand}} \times 100\right) = 85\%$

Sacramento Basin Hydrologic Study Area

The Sacramento River watershed supplies 30 percent of the runoff in California. Comprising 17 percent of the state's land area, the basin produces 22 million acre-feet (27,000 cubic hectometres) of the state's 70 million acre-feet (86,000 cubic hectometres). Major tributary streams are the American, Feather, Pit, McCloud, and upper Sacramento Rivers (Figure 12).

Water is used and reused extensively throughout the basin to meet demands for irrigation, navigation, power production, recreation-wildlife, and municipal-industrial use. Water that is surplus to in-basin needs is currently diverted to the San Joaquin Valley, Southern California, and the San Francisco Bay Area, and provides freshwater inflow to the Delta and San Francisco Bay necessary to maintain sensitive estuarine environments.

Present Agricultural Water Use

Table 17 indicates that 1,530,200 acres (619,250 square hectometres) in the Sacramento Basin are presently irrigated. Of these, about 16 percent, or 250,000 acres (100,000 square hectometres), are irrigated in mountain valleys and along stream courses above the valley floor.

The main agricultural area is the Sacramento Valley floodplain. Water is provided to this area through a complex series of ditches, canals, and drains, or from ground water. Irrigators divert water directly from stream channels or drains on the basis of riparian and appropriative rights, purchase water from large private irrigation or water districts, or contract for purchase from the U.S. Bureau of Reclamation Central Valley Project.

Opportunities for Water Savings

Sacramento Basin Mountain Valleys. Water in the upland tributary areas, such as the Sierra, Fall River, or Big Valleys, is used primarily to produce forage for cattle production. Historically, these areas were settled shortly after the California gold rush; appropriative water rights date back to the 1860s. In general, the lack of adequate reservoir storage intensifies the late summer drought in these valleys, where irrigators are dependent on surface water. In recent years, ground water pumping to extend the irrigation season supply has been on the increase.

Irrigators in these mountain valleys have been accused of employing wasteful wild-flooding practices in the irrigation of meadow pasture. In the springtime, pastures are spongy and water-logged due to precipitation and runoff from the surrounding area. Low-lying lands are choked with water-loving phreatophytic vegetation, generally of poor forage value. To change this situation, an ex-

TABLE 17

AGRICULTURAL LAND AND WATER USE
SACRAMENTO BASIN HYDROLOGIC STUDY AREA
1972

	Area		Average unit applied water		Range in unit applied water		Applied water	
Irrigated lands	1,000 acres	square hectometres	feet	millimetres	feet	millimetres	1,000 acre-feet	cubic hectometres
Rice	311.3	126,000	7.9	2,400	6.7-9.4	2,000-2,900	2,473	3,050
Miscellaneous Field	204.1	82,600	1.9	580	1.7-2.4	520-730	385	475
Sugar Beets	72.1	29,200	3.0	910	2.9-3.3	880-1,000	219	270
Alfalfa	130.5	52,810	3.6	1,100	3.2-4.1	980-1,250	474	585
Pasture	386.8	156,500	3.7	1,130	3.4-5.1	1,040-1,550	1,416	1,747
Miscellaneous Field	89.8	36,300	2.1	640	1.6-3.0	490-910	191	236
Deciduous Orchard	265.9	107,600	2.9	880	2.1-3.1	640-940	763	941
Subtropical Orchard	17.4	7,040	2.5	760	2.5-2.8	760-850	45	56
Vineyard	3.4	1,400	2.3	700	2.3-3.0	700-910	8	10
Grain	48.9	19,800	0.9	270	0.9-1.0	270-300	43	53
Total	1,530.2	619,250					6,017	7,423

Evapotranspiration of applied water (ETAW) = 3,487,000 acre-feet (4,301 cubic hectometres)
Net basin demand = 5,174,000 acre-feet (6,382 cubic hectometres)

$$\text{Hydrologic area efficiency} = \left(\frac{\text{ETAW}}{\text{net basin demand}} \times 100\right) = 67\%$$

AVERAGE ANNUAL RUNOFF - 22,340,000 ac.-ft
(27,560 cubic hectometres)

IRRIGABLE LAND - - 4,250,000 acres (1972)
(1,720,000 square hectometres)

IRRIGATED LAND - - - - 1,530,200 acres (1972)
(619,240 square hectometres)

URBAN LAND - - - - - 215,000 acres (1972)
(87,000 square hectometres)

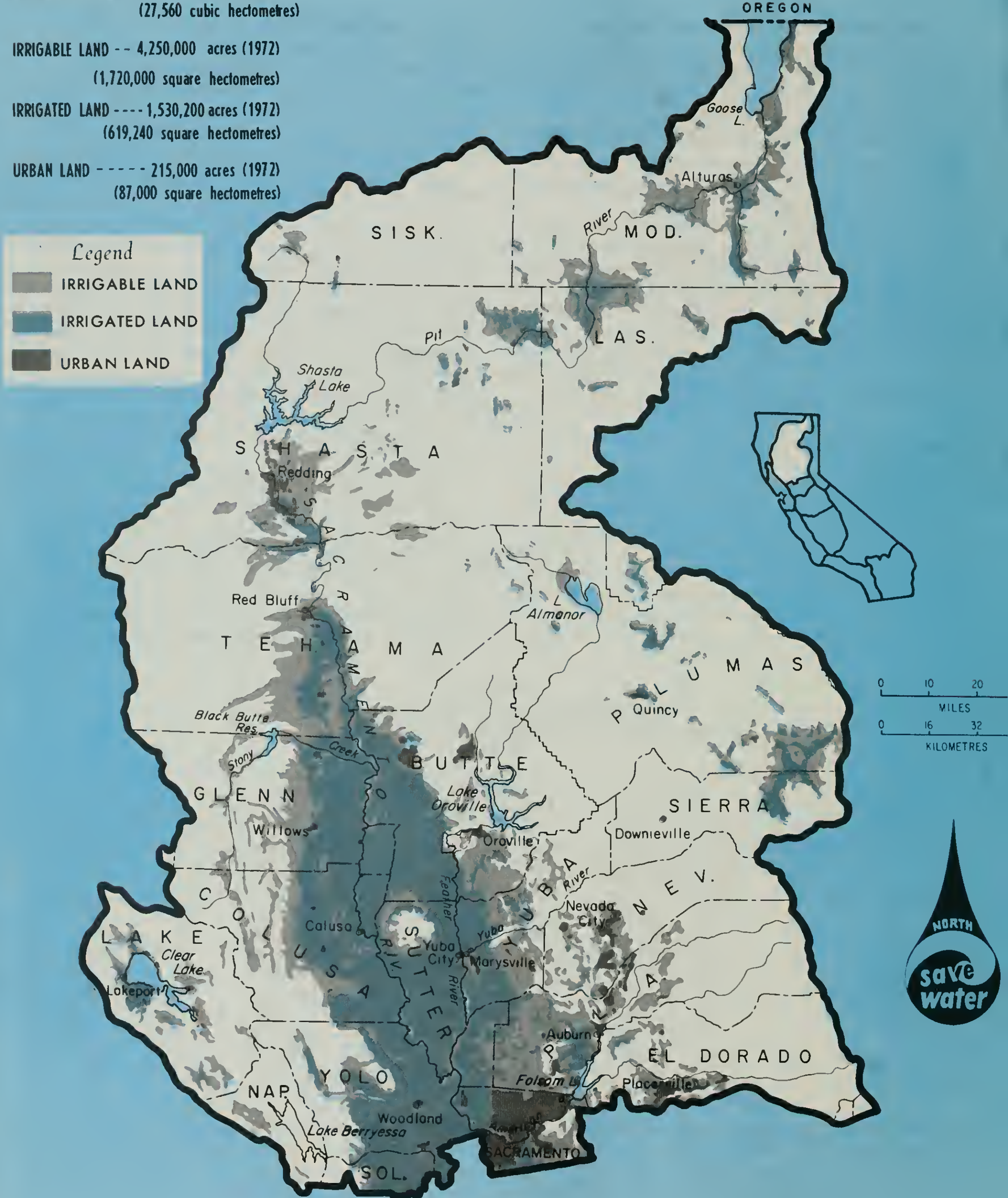


FIGURE 12
SACRAMENTO BASIN HYDROLOGIC STUDY AREA

tensive system of drainage ditches would eliminate water logging of low-lying lands, stimulate forage plant growth, and increase the water supply to downstream areas through increased runoff.

True water savings in the immediate area, however, can be achieved only by developing stream storage and conserving runoff for use later in the season. The construction of small storage reservoirs should be encouraged. Progress in this area is being made, mainly through incentive programs provided by the federal Soil Conservation Service.

On the negative side, the draining of low-lying areas reduces marshland habitat needed for the survival of certain wildlife. Marshland is the most endangered type of habitat in California.

The mountainous areas of the Sierra Nevada, Cascade, and Warner Mountains contain extensive networks of irrigation ditches, many of which traverse miles of variable terrain. Conveyance water losses are often great, because most of these ditches are unlined earth sections. On the other hand, seepage from these ditches, in many cases, feeds extensive areas of native vegetation. Lining these ditches could save water, but would also threaten riparian habitat necessary for the survival of certain wildlife species.

Sacramento Valley Floor. Historically, the use of valley floor agricultural lands, particularly those adjacent to the main tributary streams, was inhibited by severe flooding, the inability to physically develop a water supply, and the lack of demand for agricultural products. These are not problems today; the danger of flooding has been greatly reduced, water is available from canals or from the underground, and there is a large demand for California agricultural products.

Increases in irrigated acreage (there are 2.7 million remaining irrigable acres — 1.1 million square hectometres) in the Sacramento Basin) will probably be restricted only by lack of a water supply. Opportunities still exist, however, to irrigate some of this acreage and meet the increasing agricultural demand by using the existing water supplies more efficiently.

The overall Sacramento River Basin irrigation water use efficiency is about 67 percent (Table 17). The remainder, or 33 percent, recharges the ground water basins, is used by wetland phreatophytic vegetation, or flows out of the basin for downstream uses, such as agricultural water supplies, navigation control, delta salinity regulation, and delta export.

At present, return flow water is of good mineral quality, with TDS concentrations of less than 700 milligrams per litre. Turbidity is probably the most critical parameter. Agricultural drain water presently has high levels of suspended organic material, algae, and colloidal-sized soil particles.

Table 17 indicates a wide range in the quantities of water farmers apply within the Sacramento Basin. The most notable example is water applied to rice, which ranges from 6.7 to 9.4 feet (2-2.9 metres) per year between various areas or organized districts. Individual field values are known to vary from a low of 6 feet (1.8 metres), under optimum soil and management conditions, to over 12 feet (3.6 metres) under less favorable conditions.

The present irrigation practice on rice is to pond about 9 inches (230 millimetres) of water over the soil surface throughout the growing season. The ET loss over the field is about 3.4 feet (1 metre) during the season); however, the water lost to ET is replaced by continuous inflow to the field. Under optimum conditions, inflow to the field is adjusted to be equal to or only slightly greater than ET. With careful management, only small quantities of water will be spilled.

Excessive tailwater spill or growing rice on excessively permeable soils are practices that reduce farm irrigation efficiency. However, percolating water and excessive spills recharge ground water, supply downstream users, and support phreatophytic riparian vegetation, fish, and wildlife.

There is no doubt that agricultural water can be saved in the Sacramento Basin by more careful use of present supplies. Table 18 lists practices that would increase the efficiency of agricultural water use.

Some of the costs involved in these savings would be:

- increased energy for pumping.
- increased labor cost for irrigation management.
- increased concentration of pollutants in return flows.
- decreased outflows to the Delta (which would be met by higher reservoir releases).
- reduced wildlife habitat and fish flows.

Recent studies by the Department of Water Resources indicate that on the west side of the Sacramento River, where 350,000 acres (140 square hectometres) are irrigated annually in Glenn and Colusa Counties, water-use efficiency averages 70 percent from April through September. About 1,500,000 acre-feet (1,800 cubic hectometres) of water is diverted annually from the Sacramento River or pumped from underground. Of this,

TABLE 18

SACRAMENTO BASIN AND DELTA-CENTRAL SIERRA HYDROLOGIC STUDY AREAS PRACTICES TO INCREASE THE EFFECTIVENESS OF AGRICULTURAL WATER USE

Practice	Opportunity for Water Saving	Agricultural Viewpoint		Fish-Wildlife-Recreation Viewpoint		Comments
		Positive	Negative	Positive	Negative	
Increase ground water pumpage	Possibly very large.	Farmers gain operating independence and dry-year flexibility.	High initial cost; big energy user.	Reduces diversions from river.	May increase percolation.	One of two true means of saving water in basins.
Increase reservoir storage.	Moderately large.	Increased dry-year supply.	None.	Decreases peak flows; increases dry-year summer flows; enhances reservoir-type fisheries.	Would flood out native lands.	Opportunity for true in-basin water savings.
Reduce water applied to rice.	Large, possibly several hundred thousand acre-feet.	Should produce a large net saving in applied water use; save energy and fertility.	Would increase irrigation management costs; increase TDS of drainage water.	Would tend to reduce diversions from the Sacramento River, leaving more water for in-channel use.	Would decrease drain flows, hence diminish riparian vegetation and fish flows, increase TDS and water temperatures.	No savings would result unless storage provided.
Level all rice paddies, form rectangles.	Included in above.	Would decrease applied water use by an estimated 5%, increase yield, reduce water management and harvest costs, increase net profit.	Would take land out of production for one crop year; require capital outlay.	Included in above.	Elimination of berms would reduce wildlife habitat.	Now catching on rapidly in rice-growing areas.
Drain wet mountain meadows. Improve water management.	Small.	Would reduce water use; increase forage production.	Would require annual maintenance cost; high original investment.	None.	Would reduce wetland habitat, reduce late summer downstream flows.	As time goes on, practice will be employed through the incentive to increase forage production.
District practices: canal lining (reduce seepage), increased use of relift pumps, control ditch bank vegetation, clear channels.	Large, could reduce district demands.	These practices will decrease water demands on a district basis; could increase yields and decrease fertilizer needs.	Would require more energy, capital, and manpower, increase the unit cost of water, leave drain water users with no available supply.	None.	Would reduce wetland habitat, reduce fish flows, raise water temperatures, increase TDS, concentrate pesticides, and increase channel velocities in some areas.	Must develop incentives for districts to take action. Must persuade people that water-saving practices are necessary.

300,000 acre-feet (370 cubic hectometres) returns to the river system through a series of drains.

The question is logically asked, "Would an increase in on-farm and overall basin efficiency, meaning fewer diversion needs from the Sacramento River, merely be reflected by lower return flows?" Studies now in progress indicate that the answer to this question is yes — that is, no real gain in water supply could be made. This is because return flows from irrigation become part of the water supply to downstream areas. (Water "saved" in this case would merely have to be replaced from storage.)

True water savings in the Sacramento Basin can be obtained only through additional storage. The San Joaquin and Tulare Basin HSA's, unlike the Sacramento Basin, have a large ground water extraction capability which acts as a cushion against drought by, ideally, allowing short-term overdraft on ground water basins during years of short surface supply.

Institutional arrangements among local, state, and federal agencies, power companies, and other groups (such as recreation, fish and wildlife interests) are needed to best manage the waters in the Sacramento Basin. In addition, studies are needed to optimize the operation of existing reservoirs for flood and downstream seepage control and navigation, fish, and recreation needs. This may alter existing flood control criteria and releases of water for hydroelectric generation.

Irrigators along the river must be made aware of the recreational potential of the Sacramento River and its tributaries and its value to an increasing population. Institutional arrangements could maximize total benefits, but certain interest groups may suffer, possibly because of land use control or the re-evaluation of long-established water rights.

Delta-Central Sierra Hydrologic Study Area

The Delta-Central Sierra HSA occupies the area where the two main rivers of the great Central Valley, the Sacramento and San Joaquin, meet before turning west into San Francisco Bay. The study area includes 700,000 acres (280,000 square hectometres) of waterways and delta islands. To the east is an area of sloping alluvial floodplain giving way to the portion of the Sierra Nevada drained by the Cosumnes, Mokelumne, and Calaveras Rivers. Elevations of as much as 20 feet (6 metres) below sea level in the Delta gradually increase to over 9,000 feet (2,700 metres) at the crest of the Sierra. The mean annual runoff of the basin is about 1.6 million acre-feet (2,000 cubic hectometres) (see Figure 13).

Present Agricultural Water Use

Favorable climatic conditions, ample water supplies, and outstanding soil make the Delta-Central Sierra HSA one of California's most productive agricultural regions. Table 19 indicates that 827,600 acres (334,900 square hectometres) are currently irrigated. Applied water demands for these lands total 2,474,000 acre-feet (3,052 cubic hectometres). Due to reuse of return flow, net, or system, demand is 2,085,000 acre-feet (2,572 cubic hectometres); basinwide irrigation efficiency is 80 percent.

This rather high efficiency is the result of the unique hydrologic situation in the Delta Islands, where water levels are maintained a few feet below the soil surface by a series of strategically placed drains, ditches, and pumping plants. Applied water for irrigation that percolates below the plant root zone can be pumped back out into surrounding channels where it again becomes part of the water supply.

In upland areas, conveyance losses tend to be large within the immediate area, but most return to

TABLE 19

AGRICULTURAL LAND AND WATER USE
DELTA-CENTRAL SIERRA HYDROLOGIC STUDY AREA
1972

Irrigated lands	Area		Average unit applied water		Range in unit applied water		Applied water	
	1,000 acres	square hectometres	feet	millimetres	feet	millimetres	1,000 acre-feet	cubic hectometres
Miscellaneous Field	241.4	97,700	2.2	670	1.7-2.4	520-730	547	675
Alfalfa	83.9	33,950	3.9	1,200	–		330	407
Pasture	150.8	61,000	4.3	1,300	–		657	810
Miscellaneous Truck	115.2	46,600	2.5	760	2.2-2.6	670-790	298	368
Orchard	78.6	31,800	3.2	980	1.9-3.7	580-1,100	260	320
Grapes	43.7	17,700	2.4	730	–		105	130
Sugar Beets	64.1	25,950	3.0	910	2.9-3.2	880-980	194	239
Rice	7.4	3,000	7.7	2,300	7.0-8.2	2,100-2,500	58	72
Grain	42.5	17,200	0.6	200	0.4-0.6	120-200	25	31
Total	827.6	334,900					2,474	3,052

Evapotranspiration of applied water (ETAW) = 1,671,000 acre-feet (2,061 cubic hectometres)
Net basin demand = 2,085,000 acre-feet (2,572 cubic hectometres)

Hydrologic area efficiency = $(\frac{\text{ETAW}}{\text{net basin demand}} \times 100) = 80\%$

AVERAGE ANNUAL RUNOFF - 1,600,000 ac-ft
(2,000 cubic hectometres)

IRRIGABLE LAND - 1,700,000 acres (1972)
(690,000 square hectometres)

IRRIGATED LAND - 827,600 acres (1972)
(334,900 square hectometres)

URBAN LAND - 75,000 acres (1972)
(30,000 square hectometres)

Legend

IRRIGABLE LAND
IRRIGATED LAND
URBAN LAND

0 10 20 30
MILES
0 16 32 48
KILOMETRES

FIGURE 13
DELTA-CENTRAL SIERRA HYDROLOGIC STUDY AREA

major streams for reuse in downstream areas, and eventually the residual ends up in the Delta channels and sloughs.

East of the Delta Islands on the broad alluvial floodplain running east to the Sierra foothills, the major source of water today is ground water. Despite surface water imports into this area, current overdraft is estimated at 100,000 acre-feet (120 cubic hectometres) per year, mainly in eastern San Joaquin County.

Irrigation applications in the HSA are estimated to be 10 percent by sprinkler, 10 percent by subirrigation on peaty soils, and the remainder by gravity methods. From a practical and cost standpoint, the use of drip irrigation will probably be restricted to orchard and vineyard crops. Presently, only 100 acres (40 square hectometres) of orchard are irrigated by this method.

Opportunities for Water Saving

Table 19 shows that the basinwide efficiency of the hydrologic study area is 80 percent. On the Delta Islands, water use efficiency approaches 100 percent in that no matter how much water is applied, losses are by ET only; all excess water returns to the free water table. On the other hand, low on-farm applied water use efficiency results in higher-than-necessary power consumption for pump operation.

Consequences of Improved Irrigation Practices

The consequences of increasing irrigation efficiencies are varied. For instance, excess irrigation water originating from agricultural return flows eventually ends in the Delta and adds to the Delta supply for reuse, for export, or for salinity repulsion. En route, some portion recharges the ground water or is reused by downstream irrigators. The residual entering the Delta also helps flush streams and channels. The effect of increased efficiency would frustrate these purposes. Table 18 shows the advantages and disadvantages of practices that would save prime water supplies.

San Joaquin Basin Hydrologic Study Area

The San Joaquin River Basin is located south of the Sacramento-San Joaquin Delta and includes all of the drainage areas of the San Joaquin, Merced, Tuolumne, and Stanislaus Rivers, plus those of a few small west side streams. The San Joaquin Basin HSA is an area of seemingly abundant water supply. In addition to an average annual runoff of around 6.4 million acre-feet, (7,900 cubic hectometres), over 1.4 million acre-feet (1,725 cubic hectometres) is imported into the basin annually from the Delta through the Delta Mendota Canal (Figure 14). Exports from the basin through the Friant-Kern Canal and Hetch Hetchy Aqueduct are about equal to imports at 1.4 million acre-feet (1,725 cubic hectometres).

In spite of these large water supplies, some areas within the San Joaquin Basin HSA are water deficient. Studies conducted by the Department estimate that the current (1972) deficiency is about 250,000 acre-feet (310 cubic hectometres) which represents the water needed to meet current ground water overdraft.

Present Agricultural Water Use

Table 20 shows that 1,363,700 acres (551,800 square hectometres) are currently irrigated within the San Joaquin Basin HSA. These lands require 5,446,000 acre-feet (6,717 cubic hectometres) of applied water. Most of the applied water supply, approximately 63 percent, is surface water; the remainder is from ground water sources. Applied water demand is reduced to a system or net demand of 4,466,000 acre-feet (5,509 cubic hectometres) through in-basin reuse.

Of the presently irrigated lands, less than 1 percent lie in the mountainous Sierra Nevada uplands on the east side of the hydrologic study area. The major irrigated area is on the main valley floor.

Table 20 shows a difference of 1,218,000 acre-feet (1,502 cubic hectometres) of water between the ET of applied water and net demand in the basin. This difference represents in-basin use by riparian vegetation and basin outflow (supply to the Delta).

Opportunities for Water Savings

Increases in farm-applied water use efficiency would produce a concurrent decrease in demand on prime surface and ground water supplies. Both ground water overdraft and surface drainage flows would be reduced. There are areas where over-application of surface-applied water on permeable soils has created fairly extensive areas of shallow ground water where little or no ground water pumpage now occurs. Examples of this are found in the South San Joaquin Irrigation District near Manteca, where water tables are in the 20-foot (6-metre) range, and in the federal service areas west of the San Joaquin River north of Firebaugh. Some of the high-water-table problems in this latter area have been blamed on excess seepage from the Delta Mendota Canal.

AVERAGE ANNUAL RUNOFF - 6,370,000 ac-ft
(7,860 cubic hectometres)

IRRIGABLE LAND - 2,510,000 acres (1972)
(1,020,000 square hectometres)

IRRIGATED LAND - 1,363,700 acres (1972)
(551,880 square hectometres)

URBAN LAND - 55,000 acres (1972)
(22,000 square hectometres)

FIGURE 14
SAN JOAQUIN BASIN HYDROLOGIC STUDY AREA

TABLE 20

AGRICULTURAL LAND AND WATER USE
SAN JOAQUIN BASIN HYDROLOGIC STUDY AREA
1972

Irrigated lands	Area		Average unit applied water		Range in unit applied water		Applied water	
	1,000 acres	square hectometres	feet	millimetres	feet	millimetres	1,000 acre-feet	cubic hectometres
Rice	25.7	10,400	6.7	2,000	–		172	212
Miscellaneous Field	178.5	72,240	2.7	820	2.0-3.4	610-1,000	480	592
Sugar Beets	25.0	10,100	3.8	1,200	3.2-5.0	980-1,500	96	118
Alfalfa	219.6	88,870	4.7	1,400	4.0-5.6	1,200-1,700	1,043	1,287
Pasture	319.5	129,300	5.7	1,700	4.4-7.0	1,300-2,100	1,828	2,255
Miscellaneous Truck	61.0	24,700	1.9	580	–		116	143
Cotton	93.4	37,800	3.8	1,200	3.0-5.0	910-1,500	356	439
Tomatoes	29.0	11,700	3.0	910	1.9-3.5	580-1,100	88	109
Deciduous Orchard	242.2	98,000	3.4	1,000	3.0-6.0	910-1,800	815	1,005
Subtropical Orchard	6.7	2,700	2.7	820	2.0-2.8	600-850	18	22
Vineyard	104.5	42,290	3.4	1,000	2.2-5.0	670-1,500	352	434
Grain	58.6	23,700	1.4	430	0.9-3.0	270-910	82	101
Total	1,363.7	551,800					5,446	6,717

Evapotranspiration of applied water (ETAW) = 3,248,000 acre-feet (4,006 cubic hectometres)
Net basin demand = 4,466,000 acre-feet (5,509 cubic hectometres)

Hydrologic area efficiency = $(\frac{\text{ETAW}}{\text{net basin demand}} \times 100) = 73\%$

In other areas, such as the Modesto, Turlock, and Merced Irrigation Districts, considerable pumping is required to keep the ground water below the root zone. If the excessive quantities of water applied in such areas were reduced, the need for this energy-consuming pumpage would be decreased, and additional acreage could be served with presently available surface supplies. On the other hand, planned conjunctive use of surface and ground water in such areas could increase ground water storage and enable increased conservation of excess runoff during wet years. In addition, the need for expensive subsurface soil drainage and drain pumpage would likely be reduced.

In 1972, an estimated 90 percent of the crop acreage in the San Joaquin Basin was irrigated by gravity methods. Land leveling, releveling, or otherwise maintaining a good irrigation grade would obviously provide better irrigation control. However, this would be very expensive, or perhaps impossible, in some of the shallow east side soils devoted to pasture.

About 3.4 million acre-feet (4,200 cubic hectometres) of applied irrigation water used in this basin is from surface sources. Of this, 95 percent, or 3.2 million acre-feet (4,000 cubic hectometres), is distributed by water agencies. A modified delivery schedule that enables the farmer to get water when he needs it, and take it only when he needs it, could save water. However, most districts, at present, do not have the capability within their systems to operate in this manner. A general improvement in operating practices implies better measurement of water. This would mean additional expense to the district for additional labor and equipment.

Measures that might be taken to save water in the San Joaquin HSA — both on the farm and by agencies — are listed in Table 21.

TABLE 21

SAN JOAQUIN AND TULARE LAKE BASINS HYDROLOGIC STUDY AREAS PRACTICES TO INCREASE THE EFFECTIVENESS OF AGRICULTURAL WATER USE

Practice	Opportunity for Water Saving	Agricultural Viewpoint		Fish-Wildlife-Recreation Viewpoint		Comments
		Positive	Negative	Positive	Negative	
Improved irrigation management — includes items below.	Large; decreases demand on prime supply.	Practice applicable to all applied water regardless of source. Could increase crop yields, decrease fertilizer use.	Increased irrigation costs (higher labor input).	May leave more water in channel, increase fish flows — create water for other than agricultural use.	All farm measures to reduce water waste will reduce artificially induced wetland habitat — i.e., phreatophytes and other vegetation along canals and drains.	Improved management of existing irrigation systems can reduce water applications. In some cases, a change from gravity systems to sprinkler or drip would not significantly increase efficiency.
Land leveling and smoothing.	Moderate, allows for uniform application.	Decreased water use, higher yield through uniform stand, ease in harvest.	Expensive. May take land out of production for one year.	Same as above.	Effect of individual practices is small; in aggregate, the effect is cumulative and produces a large negative impact on fish and wildlife.	Not possible where soils are shallow or subsidence is a problem (valley west side).
Pipeline, gated pipe.	Big water saver — ideal for controlling point application.	Saves water, allows great flexibility and mobility in water application over a large farm acreage from a single water source.	Expensive. Requires additional energy for booster pumps, additional manpower.	Same as above.	Same as above.	Widely used in development of new agricultural lands.
Sprinkler irrigation.	Moderate water saving, ideal for obtaining germination on problem soils.	Saves water, gives even water application, increases yields — land need not be leveled.	Expensive. Higher labor and energy requirements.	Same as above.	Same as above.	Currently practiced on 10 and 15 percent of lands in San Joaquin and Tulare Lake Basins, respectively.
Drip irrigation.	Not known at this time. Will probably not involve a big acreage in the Central Valley due to cost and wide variety of crops.	Saves water, allows irrigation on very steep land with shallow, rocky soil.	Expensive. Malfunction creates stress in plants due to lack of moisture in soil. Higher energy requirements. Not adaptable to all crops.	Same as above.	Same as above.	Receiving considerable attention at this time.
Tail water reuse.	Small; good irrigation management reduces tail water.	Maximizes use of water delivered to farm, should save some water, improves efficiency of furrow or flood irrigation methods.	Some costs involved. Requires a sump, pumps, and return flow system; modest energy user.	Same as above. Known to provide some limited fish and waterfowl habitat.	Same as above.	Not practiced widely today.
Irrigation management.	Overall might be moderately high.	Low cost.	Requires expenditure for water measurement devices.	Same as above.	Same as above.	Private irrigation management consultants will move into this field.

Continued

TABLE 21 (continued)

SAN JOAQUIN AND TULARE LAKE BASINS HYDROLOGIC STUDY AREAS
PRACTICES TO INCREASE THE EFFECTIVENESS OF AGRICULTURAL WATER USE

Practice	Opportunity for Water Saving	Agricultural Viewpoint		Fish-Wildlife-Recreation Viewpoint		Comments
		Positive	Negative	Positive	Negative	
More timely water deliveries.	Moderate savings in some areas.	Water available when and in amounts needed.	Would stress many existing systems. Would need more canal capacity, increased management and labor input; would increase peak period electrical energy demands.	Same as above.	Same as above.	Not a problem in many areas.
Canal lining.	Reduce loss in transit — could save 10 percent or higher in some areas.	Saves water, could control high water tables, might lower maintenance costs in some instances, could increase crop suitability of adjacent lands.	Expensive. Would reduce ground water recharge and supplies to some irrigators.	Same as above.	Would reduce phreatophytic vegetation along canals — reduce wildlife habitat.	Prior to lining, capability of ground water recharge should be determined.

Tulare Basin Hydrologic Study Area

The Tulare Basin consists of the southern half of the San Joaquin Valley. The hydrologic study area is essentially a closed basin, and except for rare flood overflows from the Kings River into the San Joaquin River via Fresno Slough, all runoff percolates or evaporates without reaching the ocean. The major rivers of this basin are the Kings, Kaweah, Tule, and Kern Rivers; the mean annual runoff has been estimated at 3,320,000 acre-feet (4,100 cubic hectometres) (Figure 15).

Present Agricultural Water Use

Table 22 indicates that the Tulare Basin HSA is currently the most efficient in the State from the standpoint of use of existing water supplies. Yet, the overall basin efficiency of 96 percent indicates that salt balance is a problem. In areas near the valley trough the problem will grow in the near future.

Water resources within the basin are completely utilized. Even with large imports, the basin has a present annual deficiency of about 1.3 million acre-feet (1,600 cubic hectometres), which is being met through ground water overdraft.

Of the 10.9 million acre-feet (13,400 cubic hectometres) of applied water used in the Tulare Basin, an estimated 7.1 million acre-feet (8,700 cubic hectometres) is prime supply. Of this, approximately 5.5 million acre-feet (6,800 cubic hectometres) comes from surface sources, including 3.0 million acre-feet (3,700 cubic hectometres) from the Central Valley Project and the State Water Project. The balance, or 1.6 million acre-feet (1,975 cubic hectometres), is obtained from prime ground water sources and current overdraft.

Opportunities for Water Savings

With the present basinwide water use efficiency, increasing the effective use of water through conservation practices does not appear to be very promising. On-farm efficiency, on the other hand, is not high in all cases and improved irrigation practices can result in benefits in some areas within the basin.

In the western and southwestern portions of the Tulare Basin HSA, with a few exceptions where small streams recharge a limited quantity of water in the permeable upper portions of their alluvial fans, the quality of ground water is unfavorable, and applied water in excess of crop ET moves downward into these pools of poor quality water, where it is lost. In addition, in some areas of shallow subsurface clay layers on the lower alluvial fan, basin rim, and trough positions, percolating excess irrigation water joins shallow ground water of typically poor quality. Increased irrigation efficiency would reduce the amount of good quality water degraded by these processes.

AVERAGE ANNUAL RUNOFF - 3,320,000 ac-ft
(4,100 cubic hectometres)

IRRIGABLE LAND - 5,040,000 acres (1972)
(2,040,000 square hectometres)

IRRIGATED LAND - 3,166,000 acres (1972)
(1,281,000 square hectometres)

URBAN LAND - 135,000 acres (1972)
(54,600 square hectometres)

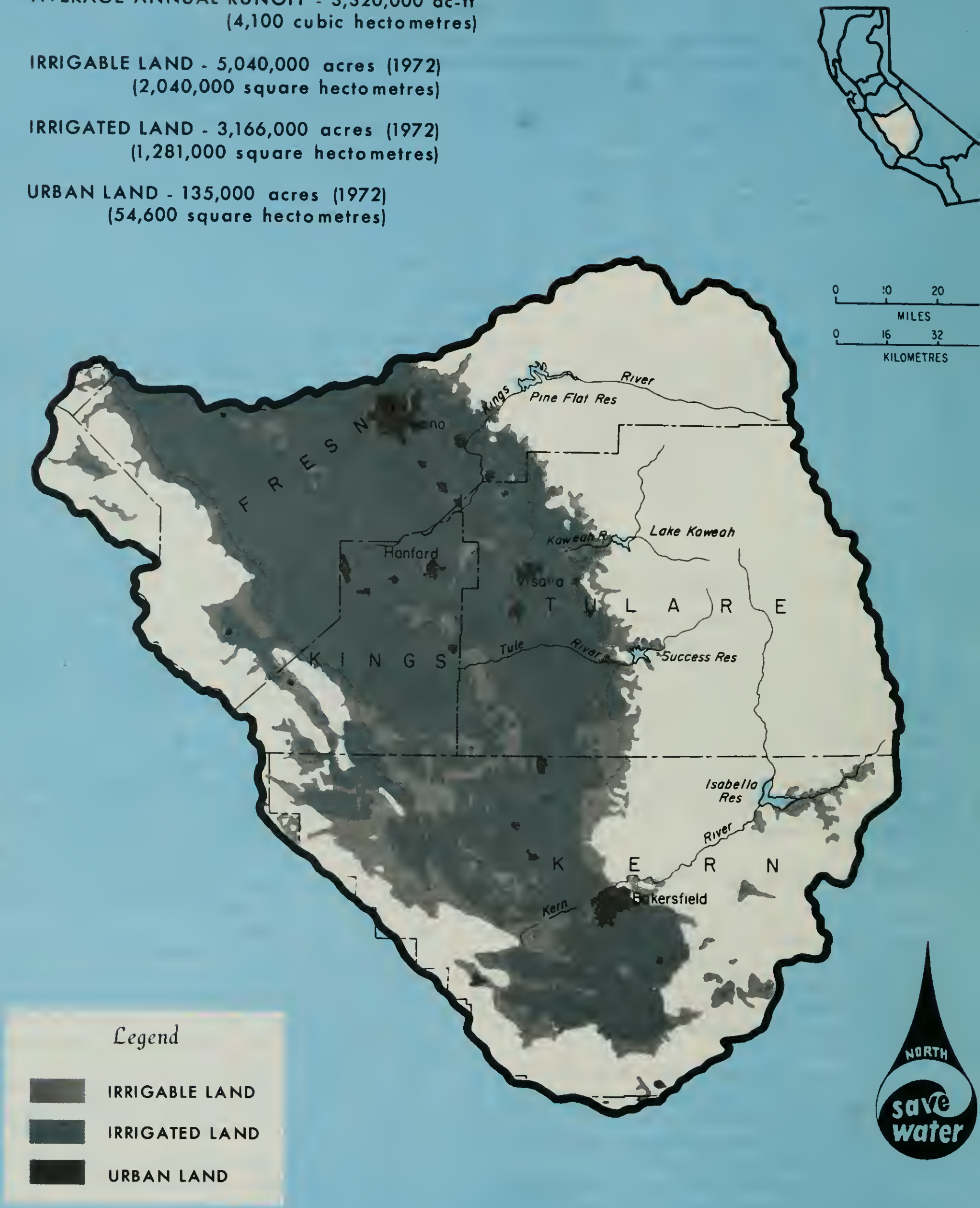


FIGURE 15
TULARE BASIN HYDROLOGIC STUDY AREA

TABLE 22

AGRICULTURAL LAND AND WATER USE
TULARE BASIN HYDROLOGIC STUDY AREA
1972

Irrigated lands	Area		Average unit applied water		Range in unit applied water		Applied water	
	1,000 acres	square hectometres	feet	millimetres	feet	millimetres	1,000 acre-feet	cubic hectometres
Rice	4.6	1,900	6.7	2,000	—		31	38
Miscellaneous Field	323.6	131,000	2.9	880	2.4-6.0	730-1,800	935	1,153
Sugar Beets	75.3	30,500	3.9	1,200	3.2-4.7	980-1,400	297	366
Alfalfa	425.2	172,100	5.1	1,600	4.0-8.0	1,200-2,400	2,160	2,664
Pasture	129.7	52,500	6.3	1,900	5.0-7.0	1,500-2,100	820	1,011
Miscellaneous Truck	118.9	48,100	2.1	640	—		249	307
Cotton	740.8	299,800	3.9	1,200	3.0-5.0	910-1,500	2,862	3,530
Tomatoes	30.1	12,200	3.3	1,000	2.5-3.5	760-1,070	98	121
Deciduous Orchard	192.2	77,800	3.7	1,100	3.0-6.0	910-1,800	716	883
Subtropical Orchard	181.1	73,300	2.8	850	2.0-3.0	610-910	503	620
Vineyard	329.5	133,300	3.9	1,200	3.0-5.0	910-1,500	1,271	1,568
Grain	615.0	248,900	1.5	460	0.5-3.0	150-910	946	1,167
Total	3,166.0	1,281,400					10,888	13,428

Evapotranspiration of applied water (ETAW) = 6,784,000 acre-feet (8,368 cubic hectometres)
Net basin demand = 7,079,000 acre-feet (8,732 cubic hectometres)

Hydrologic area efficiency = $(\frac{\text{ETAW}}{\text{net basin demand}} \times 100) = 96\%$

Many water service agencies on the east side of the valley floor have a long history of diversion from such rivers as the Kings, Kaweah, Tule, and Kern Rivers. Their distribution systems are old, and most canals are unlined. Although seepage from these canals is high, little water is lost because it percolates to usable ground water in most instances. However, reduced percolation losses would save energy, because less pumping would be required.

In addition, as water percolates through the soil, water quality is degraded to some extent. Accordingly, reduced deep percolation from canals, or on-farm, would reduce the quantity of salts in the total water supply. This is particularly important in areas such as the Tulare Basin, where exportation of salts is a major water-management problem.

Measures that might be taken to improve water management in the Tulare Basin — both on-farm and by agencies — are listed in Table 21.

North Lahontan Hydrologic Study Area

The North Lahontan HSA is part of the Great Basin, a large region of interior drainage. It lies east of the drainage divide between the Central Valley and the streams that flow either into Nevada or into closed intermittent lakes on the California side. The crest of the Sierra-Nevada forms the westerly boundary in the southern and central portions of the area, while the Warner Mountains separate the North Lahontan from the Pit River Basin in the north. The eastern boundary of the HSA is the Nevada state line extending from Oregon south to the southern edge of the Walker River catchment in Mono County (Figure 16).

Physiographically, the North Lahontan HSA consists of rugged mountains and high mountain valleys. The rivers and streams within the area are fed mainly from snowmelt. Little reservoir storage exists in this region; consequently, irrigators depend on spring and early summer runoff for most of their irrigation supplies.

Agriculture in the region is tied mainly to the production of livestock; a limited acreage of truck crops are grown in Surprise Valley (Table 23). Water rights dating back to the early 1860's predominate.

Only two areas in the HSA (Surprise Valley and the Susan River area) have any appreciable ground water development. The expanded use of ground water in these two areas will probably comprise the major portion of the area's future agricultural growth.

AVERAGE ANNUAL RUNOFF - 1,840,000 ac-ft
(2,270 cubic hectometres)

IRRIGABLE LAND ----- 610,000 acres (1972)
(250,000 square hectometres)

IRRIGATED LAND ----- 135,300 acres (1972)
(54,760 square hectometres)

URBAN LAND ------- 20,000 acres (1972)
(8,000 square hectometres)

Legend

IRRIGABLE LAND

IRRIGATED LAND

URBAN LAND

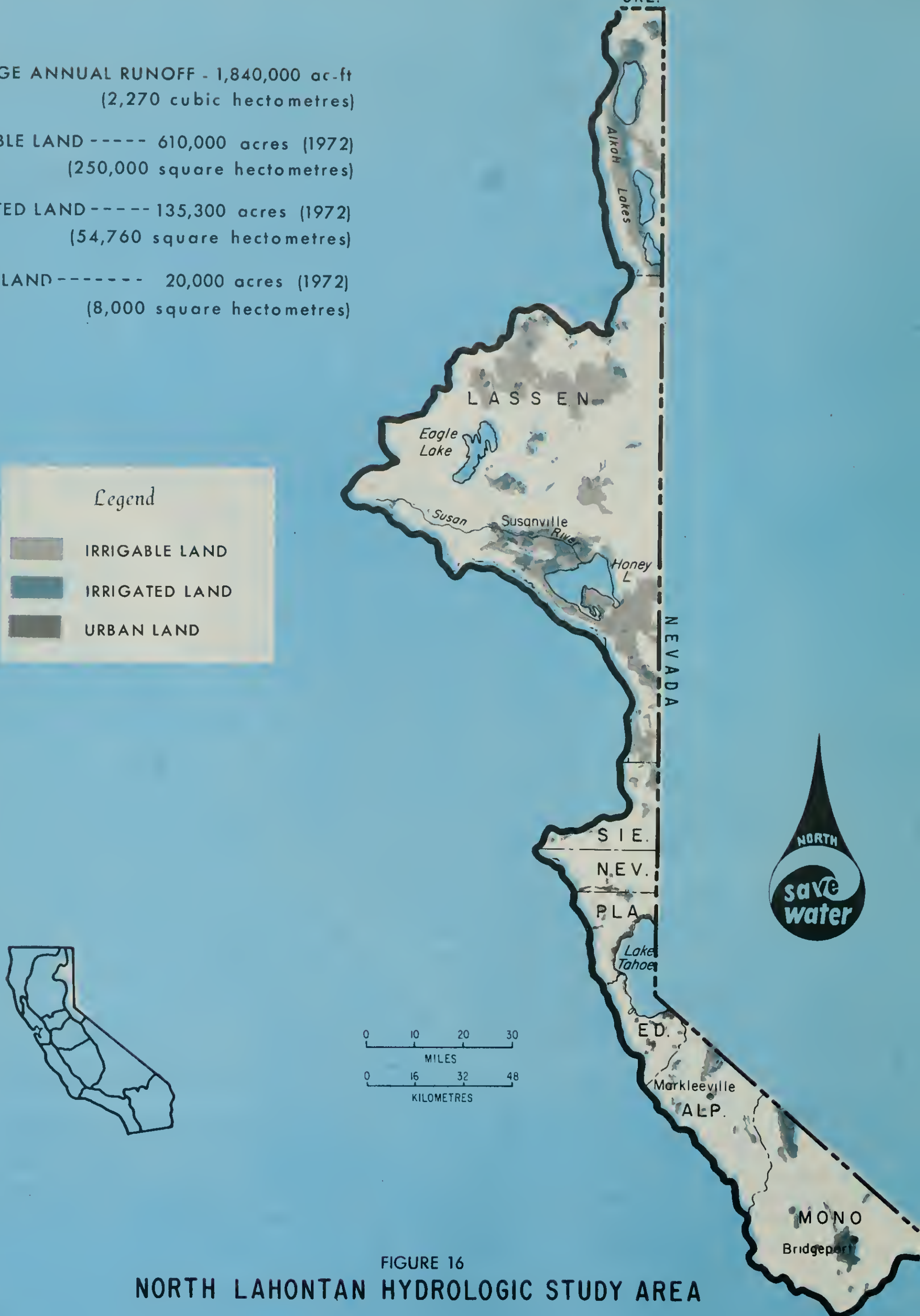


FIGURE 16
NORTH LAHONTAN HYDROLOGIC STUDY AREA

Agricultural Water Use

In average or wet years the normal spring runoff exceeds the agricultural need; water wastes away to alkali lakes or runs eastward into Nevada. A major savings, which might enable agriculture to stretch its present water supplies, could be attained by spreading excess spring runoff to recharge existing ground water basins. Then, during dry years, these ground water basins could be pumped. The main roadblock to a conjunctive operation of surface and ground water in these mountain valleys is the cost of pumping compared to the low potential return from the water. Major changes in cropping practices would be required; that is, decreased pasture acreage and increased alfalfa, corn, or cereal feed grains.

Costly leveling of land and the construction of drainage ditches would greatly increase the forage production of many acres of wet meadow land. However, the saving of applied irrigation water would be small; the principal gain would be the increased forage production. Bridgeport Meadows in the East Walker River watershed of Mono County is a good example of reclamation of boggy meadow to improved pasture land.

Table 13 lists practices that might be employed to conserve water in the North Lahontan HSA.

TABLE 23

AGRICULTURAL LAND AND WATER USE
NORTH LAHONTAN HYDROLOGIC STUDY AREA
1972

	Area		Average unit applied water		Applied water	
Irrigated Lands	1,000 acres	square hectometres	feet	millimeters	1,000 acre-feet	cubic hectometres
Miscellaneous Field	0.4	160	2.5	760	1	1
Alfalfa	21.5	8,700	3.7	1,100	80	99
Mixed Pasture	61.3	24,800	4.2	1,300	256	316
Meadow Pasture	44.0	17,800	1.5	460	66	81
Miscellaneous Truck	0.3	120	3.3	1,000	1	1
Grain	7.8	3,200	2.0	600	16	20
Total	135.3	54,780			420	518

Evapotranspiration of applied water (ETAW) = 252,000 acre-feet (311 cubic hectometres)
Net basin demand = 393,000 acre-feet (485 cubic hectometres)

Hydrologic area efficiency = $(\frac{\text{ETAW}}{\text{net basin demand}} \times 100) = 64\%$

South Lahontan Hydrologic Study Area

The South Lahontan HSA is the California portion of the southern Great Basin. All of the natural runoff eventually flows into closed sinks and evaporates or percolates into ground water basins. This region includes the eastern drainage area of the Sierra Nevada and extends from Mono Lake on the north to the Mojave River drainage on the south, including the more populous Antelope Valley to the west. Death Valley and Mount Whitney, the lowest and highest points in California, are located in the South Lahontan HSA (Figure 17).

Rainfall is sparse throughout most of this desert region but increases with elevation. Runoff from the eastern slope of the Sierra Nevada provides abundant water to the Owens Valley floor. A large portion of this water is exported to the Los Angeles Basin via the Los Angeles Aqueduct.

The area encompasses slightly less than 30 million acres (12 million square hectometres), of which only 77,600 acres (31,360 square hectometres) are dedicated to irrigated agriculture (Table 24). This agriculture is generally confined to the Mono-Owens area, Antelope Valley, and the area along the Mojave River.

Water supplies for the Mono-Owens area are derived from a combination of surface water and ground water sources. Antelope Valley derives its water from wells, which are recharged by percolating runoff from the surrounding mountains. The Mojave River area also depends on wells along the river, which are recharged by runoff from the San Bernardino Mountains.

FIGURE 17

SOUTH LAHONTON HYDROLOGIC STUDY AREA

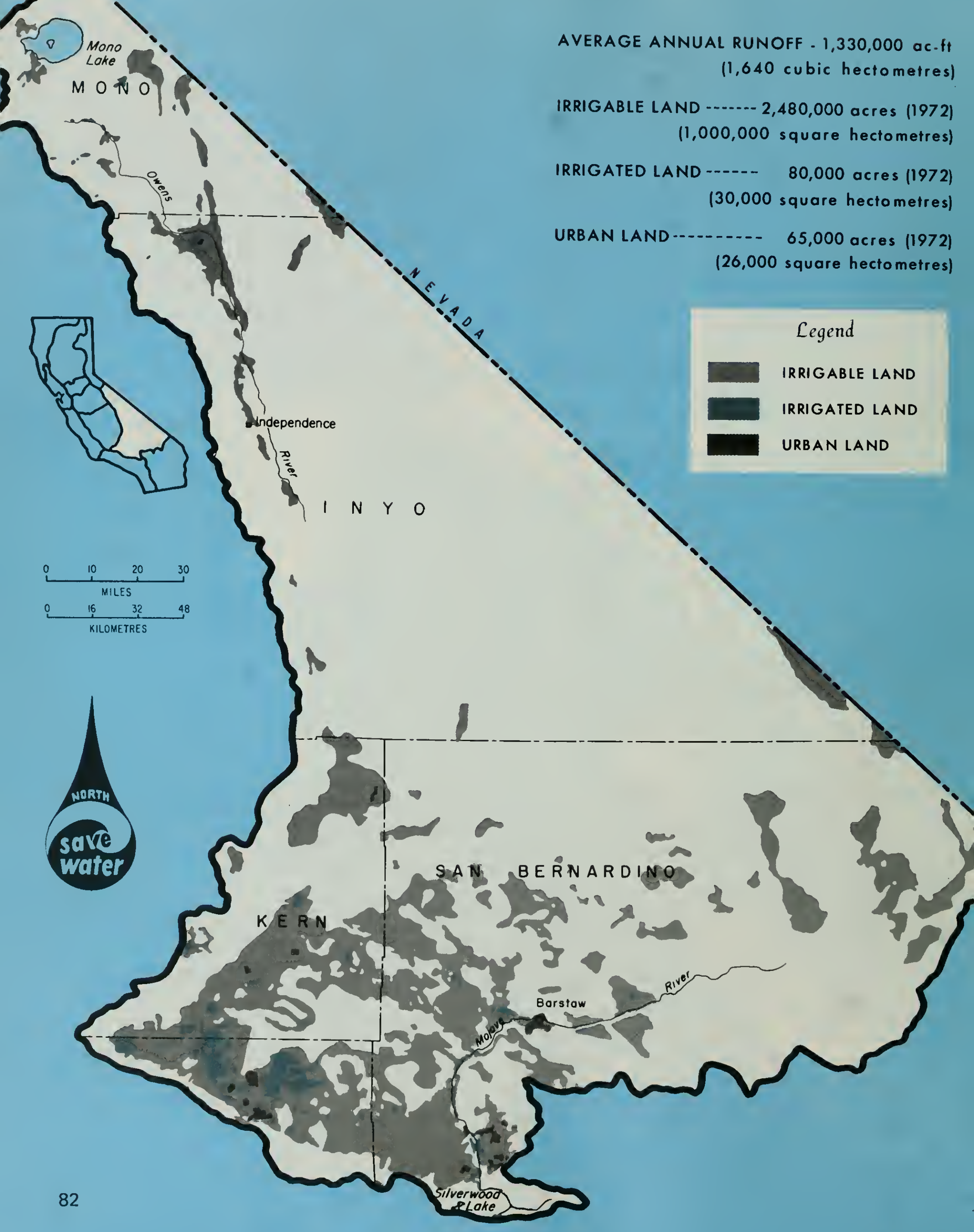


TABLE 24

AGRICULTURAL LAND AND WATER USE
SOUTH LAHONTAN HYDROLOGIC STUDY AREA
1972

Irrigated lands	Area		Average unit applied water		Range in unit applied water		Applied water	
	1,000 acres	square hectometres	feet	millimetres	feet	millimetres	1,000 acre-feet	cubic hectometres
Miscellaneous Field	1.1	450	2.7	820	–		3	4
Sugar Beets	2.8	1,100	2.9	880	–		8	10
Alfalfa	57.6	23,300	4.2	1,300	4.0-4.3	1,200-1,300	242	299
Pasture	10.8	4,370	3.8	1,200	3.7-4.0	1,100-1,200	41	51
Truck Crops	1.0	400	2.0	610	–		2	2
Deciduous Orchard	2.3	930	3.5	1,100	–		8	10
Vineyard	0.1	40	3.4	1,000	–		–	–
Cereal Grains	1.9	770	1.0	300	–		2	2
Total	77.6	31,360					306	378

Evapotranspiration of applied water (ETAW) = 204,000 acre-feet (251 cubic hectometres)
Net basin demand = 225,000 acre-feet (277 cubic hectometres)

Hydrologic area efficiency = $(\frac{\text{ETAW}}{\text{net basin demand}} \times 100) = 91\%$

Present Agricultural Water Use

The Mono-Owens area is unique in that the City of Los Angeles owns most of the nonfederal land in the basin and its water rights. The City, therefore, controls the destiny of agriculture in the area. Crops are generally confined to alfalfa and flood-irrigated pasture. About half of the alfalfa acreage is sprinkled.

Antelope Valley, where 43,000 acres (17,000 square hectometres) are irrigated, receives its water supply mainly from limited ground water supplies and from the State Water Project. Because of land speculation and increasing subdivision of farms into noneconomic units, the future for agriculture does not appear promising. Although the present high price of alfalfa has revived interest in farming in this area, it may be only temporary.

The Mojave River area has about 15,500 acres (6,270 square hectometres) under irrigation, principally in alfalfa and pasture. Center-pivot sprinklers are becoming more common to the area and are replacing portable systems. Ground water is used in all cases; the mineral content ranges up to 500 milligrams per litre (TDS), with pockets of poorer quality water in a few areas.

Due to effective conjunctive use operations in the HSA, the overall basin water use efficiency is 90 percent.

Opportunities for Water Savings

On-farm irrigation efficiency in the Mono-Owens area is estimated at only about 60 percent. There is an opportunity here to increase efficiency by replacing flood irrigation with sprinklers on some lands. In addition, earthen canals and ditches could be lined.

In the Mojave River and Antelope Valley areas, the applied water efficiencies, which are now slightly over 70 percent, could perhaps be improved somewhat. Table 25 lists practices that would increase the efficiency of agricultural water use in the South Lahontan HSA.

TABLE 25

SOUTH LAHONTAN HYDROLOGIC STUDY AREA
PRACTICES TO INCREASE THE EFFECTIVENESS OF AGRICULTURAL WATER USE

Practice	Opportunity for Water Saving	Agricultural Viewpoint		Fish-Wildlife-Recreation Viewpoint		Comments
		Positive	Negative	Positive	Negative	
Sprinkler irrigation.	Slight to moderate.	Would reduce applied water demand; increase crop yields.	Expensive. Would require more energy.	None.	Little impact.	Fairly common now in Antelope Valley and Mojave River areas. Negative impact on conjunctive use in Mono-Owens area.
Use of soil moisture indicators.	Slight saving; would help irrigator time applications.	Would increase yield; lower applied water needs.	Some cost involved for instrumentation.	None.	Little impact in this basin.	Standard for areas with good farm management practices.
Control phreatophytes.	Increases ground water recharge and available water supply.	Would save some water for recharges.	Some cost for vegetation removal and control.	None.	Would reduce a critical habitat for wildlife.	Possible mainly in Owens Valley and along Mojave River.
Canal and ditch lining.	Slight to moderate.	Would spread developed surface water over a larger area, thus reducing pumpage.	None.	None.	Might reduce some small areas of wetland habitat.	Potential in Owens Valley.

Colorado Desert Hydrologic Study Area

The Colorado Desert HSA in southeastern California is bordered by Arizona on the east and Mexico on the south. The HSA comprises 12 million acres (4.9 million square hectometres) of desert land with an almost year-round growing season, sparse rainfall, and very hot summers (Figure 18).

The 718,000 acres (290,900 square hectometres) currently under irrigation use about 3.2 million acre-feet (3,900 cubic hectometres) of water annually. Irrigation water is supplied by surface diversions from the Colorado River and from limited ground water pumping. An important limiting factor is the water quality. TDS ranges from 700 to 1,000 ppm, depending on the location of the diversion. Because of this highly saline water, adequate leaching is critical.

Present Agricultural Water Use

Agricultural operations are carried on in three principal locations: the Coachella, Imperial, and Palo Verde Valleys. Imperial Valley is the largest agricultural area, with extensive plantings of alfalfa, truck, and field crops. In addition to these crops, citrus is grown in the Palo Verde and Coachella Valleys.

Less than one-half percent of the area is sprinkler-irrigated; present irrigation practices are divided between border and furrow irrigation. The present HSA efficiency is estimated to be 66 percent (Table 26).

Opportunities for Water Savings

Table 27 lists practices that would increase the efficiency of agricultural water use in the Colorado Desert HSA.

Although drip and sprinkler irrigation could produce water savings, neither method is very popular at present because of the high initial capital cost and the fact that the cost of water (about $3 per acre-foot) does not encourage efficient use. On the

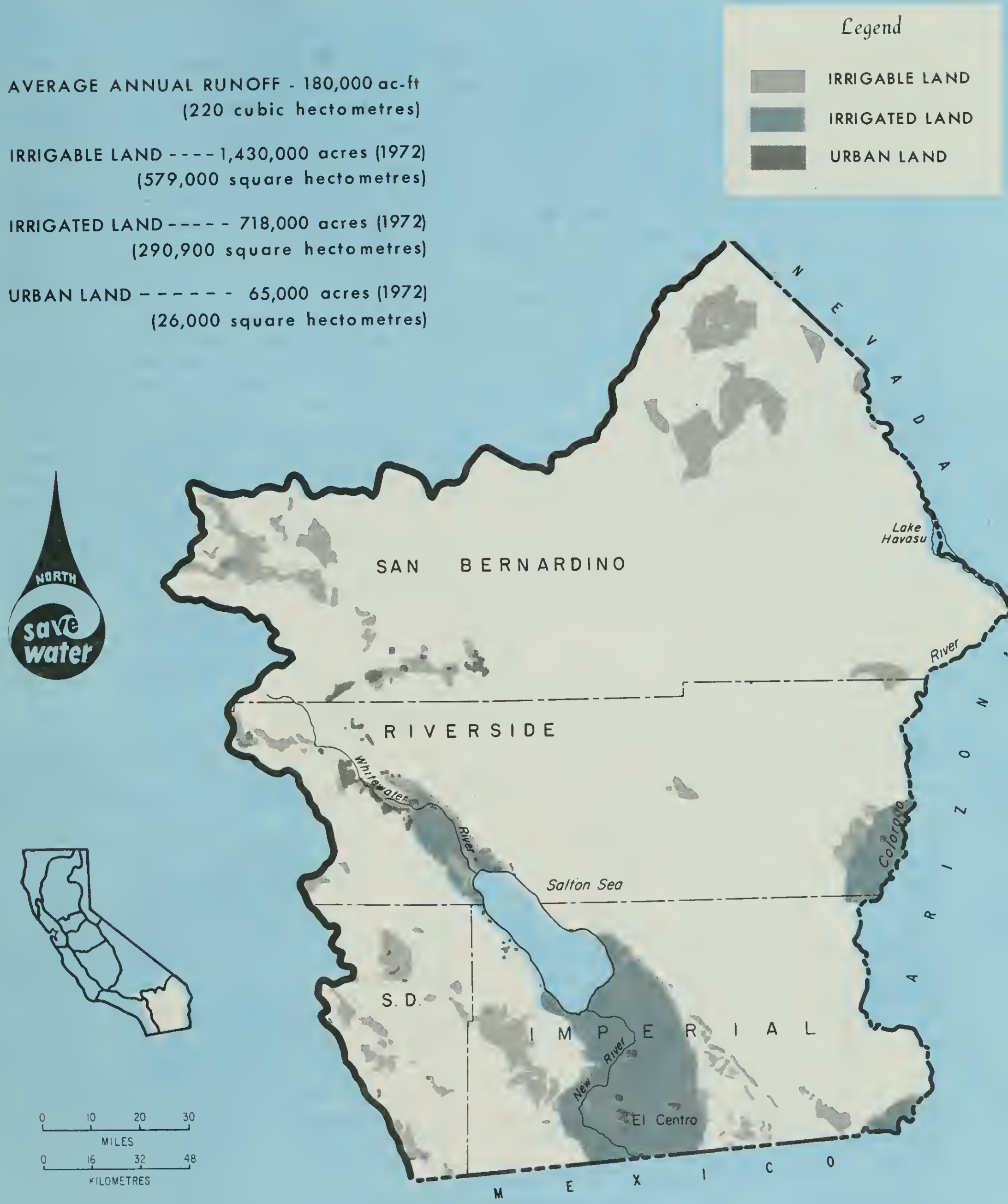


FIGURE 18
COLORADO DESERT HYDROLOGIC STUDY AREA

other hand, sprinklers not only help conserve water but also aid in seed germination, reduce root diseases, and can be used to both control frost in the spring and cool plants during the summer. Their use also eliminates certain forms of labor. Accordingly, the primary motivation for a change to sprinklers appears to be based on one or more of these reasons rather than on water conservation.

The use of sprinklers is increasing more rapidly in the Palo Verde Valley than in other areas of the HSA. In addition, the U.S. Bureau of Reclamation is operating a trial irrigation management service there. The objective is to accomplish better timing of water deliveries and application through the use of detailed climate and soils information. The Bureau's program is one of several aimed at reducing the salinity of the Colorado River.

On the other hand, improved irrigation efficiency in Palo Verde Valley may result in a problem. A small amount of drain water flowing out of the valley has been designated for cooling the Sun Desert Nuclear Power Plant, and more efficient irrigation practices would probably reduce that supply. However, if water from certain of the poorer quality level drains could be selectively used for the nuclear plant, overall water quality in the lower Colorado River could be improved.

Lining portions of the Coachella and All American Canals and district laterals could result in significant water savings, possibly as much as 250,000 acre-feet (300 cubic hectometres) per year.

In the Imperial Valley, sprinklers are not extensively used, but they are gaining acceptance for germination and cooling of lettuce.

Surface water deliveries in the Imperial Valley are made over a 24-hour period, and sometimes too much water is delivered to the farm headgate. Ditch tenders frequently have poor control over water distribution, and excess flows are lost in drainage ditches. Additional regulatory storage could reduce these operating losses.

Reductions of applied water in both Imperial and Coachella Valleys will reduce irrigation drainage, which feeds the Salton Sea. The Sea is critically affected by the quality and quantity of agricultural drainage inflow. Changes in irrigation practices could have severe environmental impact on the Sea by reducing inflow and at the same time increasing the inflow salinity.

TABLE 26

AGRICULTURAL LAND AND WATER USE
COLORADO DESERT HYDROLOGIC STUDY AREA
1972

Irrigated lands	Area		Average unit applied water		Range in unit applied water		Applied water	
	1,000 acres	square hectometres	feet	millimetres	feet	millimetres	1,000 acre-feet	cubic hectometres
Miscellaneous Field	164.9	66,700	3.7	1,100	1.3-6.6	400-2,000	603	744
Sugar Beets	61.1	24,700	4.1	1,200	2.2-6.6	670-2,000	252	311
Alfalfa	191.6	77,550	5.7	1,700	3.3-13.2	1,000-4,000	1,088	1,342
Pasture	28.5	11,500	7.6	2,300	–		216	266
Miscellaneous Truck	93.0	37,600	4.6	1,400	2.1-7.0	640-2,100	425	524
Tomatoes	2.4	970	4.6	1,400	–		11	14
Deciduous Orchard	0.6	240	3.3	1,000	–		2	2
Subtropical Orchard	33.8	13,700	6.1	1,900	6.0-9.0	1,800-2,700	207	255
Vineyard	7.9	3,200	5.4	1,600	–	–	43	53
Grain	135.0	54,600	2.7	820	1.2-4.1	370-1,200	370	456
Total	718.8[1]	290,760					3,217	3,967

Evapotranspiration of applied water (ETAW) = 2,621,000 acre-feet (3,233 cubic hectometres)[2]
Net basin demand = 3,966,000 acre-feet (4,892 cubic hectometres)

$$\text{Hydrologic area efficiency} = \left(\frac{\text{ETAW}}{\text{net basin demand}} \times 100\right) = 66\%$$

1. Includes double cropping
2. Includes 500,000 ac-ft leaching requirement.

TABLE 27

COLORADO DESERT HYDROLOGIC STUDY AREA
PRACTICES TO INCREASE THE EFFECTIVENESS OF AGRICULTURAL WATER USE

Practice	Opportunity for Water Saving	Agricultural Viewpoint		Fish-Wildlife-Recreation Viewpoint		Comments
		Positive	Negative	Positive	Negative	
Sprinkler irrigation.	Moderate.	Would save water. Would also improve germination of crops and control of soil salinity.	Would require large capital investment; would increase energy needs.	None.	Would reduce runoff and wetland habitat.	The cost of water in most areas makes this measure economically impractical.
Drip irrigation.	Small; application to a small acreage of subtropical orchard.	Would save some money.	Would involve very high capital investment.	None.	Same as above.	Water costs currently too low to make this attractive.
Reduction of tailwater.	Moderate.	Would save water.	Would increase farm management costs.	None.	Would increase TDS in drains; dry up	Main problem is with reduced quality of drainage water.
Flexibility in agency water delivery.	Higher opportunity.	Could irrigate more land with current water.	Would greatly increase operating costs to districts.	None.	Would reduce runoff to Salton Sea and increase salinity.	Greatest potential in Imperial Valley.
Irrigation management services.	Good opportunity if farmers will cooperate.	Would save both water and energy.	Would increase irrigation charge to farmers.	None.	Would reduce runoff and wetland habitat.	Irrigation automation can be incorporated into major irrigation district operations.
Canal and Ditch lining.	One of best off-farm measures; may save 10% of diverted water.	Would reduce system demand; provide more water for actual farm use.	Costly; would reduce water going to recharge ground water in some areas.	None.	Would reduce riparian habitat.	Net effect of this practice needs to be carefully analyzed.
Minimized leaching.	Slight to moderate savings possible.	Would save water by reducing application; less drainage to be managed.	Long-term effects not fully understood.	None.	Would tend to reduce riparian habitat by reducing drain water.	May have merit in this area by reducing large quantities of water currently used for leaching.
Control of phreatophytes.	Slight — not a problem here.	Would save some water.	None.	None.	Would eliminate wetland habitat.	Control should be highly selective.

Statewide Summary

To assess the potential statewide water savings from agricultural water conservation, reasonably attainable water savings in each hydrologic study area have been estimated and are summarized in Table 28. Table 28 also shows that basin efficiency varies from a low of 64 percent in the North Lahontan HSA to 96 percent in the Tulare Basin. However, high efficiency is not necessarily desirable; it must be weighed against water quality considerations; environmental factors including fish, wildlife, and recreation needs; present water abundance; water cost; current water management practices; and water rights.

To estimate feasible water savings in each of the hydrologic study areas, optimum HSA efficiencies were subjectively estimated on the basis of basin conditions (e.g., climate, crop types, soil conditions, water quality, water quantity, etc.). These optimum efficiencies are considered reasonably attainable if the on- and off-farm practices previously discussed are implemented. Tables 28 and 29 show present basin efficiency, describe the major practices that might be followed to produce actual water savings, and estimate the general range of water savings that might be achieved.

In some HSA's as in the Sacramento and San Joaquin Basins, very little actual water savings are possible through increased on-farm efficiency unless additional storage reservoirs or additional ground water recharge projects are developed to store the water conserved. This is because present reservoir storage is now committed to downstream or in-basin use. In addition, return flows from irrigation in the Sacramento and San Joaquin River Basins are actually part of the prime water supply going to the Delta to meet delta export demands, in-delta use, and delta outflow requirements. These return flows amount to 1,312,000 acre-feet (1,600 cubic hectometres) from the Sacramento Basin and 729,000 acre-feet (890 cubic hectometres) from the San Joaquin Basin.

These statewide estimates of potential water savings are admittedly subjective. However, they do represent a reasonable approximation of the impacts of agricultural water conservation on the prime water supply. As discussed in the introduction to this chapter, even though actual water saving may not be great in some areas, improvements in irrigation practices can allow different management of the water resources to accomplish additional objectives, such as increased or re-regulated in-stream flows or energy savings. These opportunities need to be identified through case studies of specific areas throughout the State.

TABLE 28

1972 WATER USE EFFICIENCY AND OPPORTUNITIES FOR WATER SAVINGS BY AGRICULTURE IN THE ELEVEN HYDROLOGIC STUDY AREAS OF CALIFORNIA

	Irrigated Land		Applied Water		Evapo-transpiration of Applied Water		Net Basin Demand		Present Basin Efficiency	Optimized Basin Efficiency	Possible Water Savings	
Hydrologic Study Area	1,000 acres	square hecto-metres	1,000 ac-ft	cubic hecto-metres	1,000 ac-ft	cubic hecto-metres	1,000 ac-ft	cubic hecto-metres	Per-cent	Per-cent	1,000 ac-ft	cubic hecto-metres
North Coastal	249	101,870	707	870	441	544	595	734	74	80	40	49
San Francisco Bay	105	42,640	249	306	172	212	245	302	70	85	40	49
Central Coastal	449	181,770	1,025	1,259	644	794	780	962	83	No increase recommended	0	0
South Coastal	431	174,640	922	1,136	646	797	760	937	85	No increase recommended	0	0
Sacramento Basin	1,530	619,250	6,017	7,423	3,487	4,301	5,174	6,382	67	75	520[1]	641[1]
Delta-Central Sierra	828	334,900	2,474	3,052	1,671	2,061	2,085	2,572	80	Recommend only minor change	0	0
San Joaquin Basin	1,364	551,800	5,446	6,717	3,248	4,006	4,466	5,509	73	75	110[2]	135[2]
Tulare Basin	2,166	1,281,400	10,888	13,428	6,784	8,368	7,079	8,732	96	Decrease to 90	-460[3]	-567[3]
North Lahontan	135	54,780	420	518	252	311	393	485	64	75	60	74
South Lahontan	78	31,360	306	378	204	251	225	277	91	No increase recommended	0	0
Colorado Desert	719	290,760	3,217	3,967	2,621	3,233	3,966	4,892	66	73	400	490

1. Theoretical saving; possible only by increasing ground water and/or surface water storage; does not include possible short-term ground water overdraft.
2. Would need to improve distribution of present water supplies within basin to offset local ground water overdraft.
3. Would need to import more water, or reduce ETAW by converting to low-water-using crops or by reducing irrigated acreage.

TABLE 29

PRACTICES TO INCREASE THE EFFECTIVENESS OF AGRICULTURAL WATER USE SUMMARY – ALL HYDROLOGIC STUDY AREAS

Hydrologic Study Area	Present Basin Efficiency (percent)	Optimized Basin Efficiency (percent)	Major Reason for Change	Major Conservation Practices
North Coastal	74	80	Increase fish flows, provide more agricultural water.	Conjunctive use of surface and ground water, ditch lining.
San Francisco Bay	70	85	Increase irrigation supply.	Improve delivery and reuse systems, increase use of ground water.
Central Coastal	83	No increase recommended.	Highly efficient at present.	Need to improve ground water basin management for supply and salt balance.
South Coastal	85	No increase recommended.	Highly efficient at present.	Large increases in drip irrigation may allow acreage increases within present water supplies.
Sacramento Basin	67	75	Conserve existing water supplies, improve total basin water management.	Institutional arrangements, district water management, conjunctive use of surface and ground water. Additional off-stream storage needed.
Delta Central Sierra	80	Only minor improvements recommended.	Correct overdraft in eastern San Joaquin County.	Increase surface supplies, decrease ground water extraction.
San Joaquin Basin	73	75	Lower water table in selected areas. Improve efficiency of applied water use, decrease local ground water overdraft.	Improve irrigation management on-farm and by districts. Line canals.
Tulare Basin	96	Lower to 90	Reduce ground water overdraft, decrease rate of salt buildup.	Moratorium on further ground water extraction, land use control, increase basin import.
North Lahontan	64	75	Increase available water supply, conserve spring runoff.	Conjunctive surface-ground water operation, increase recharge, line ditches.
South Lahontan	90	Small increase recommended.	Reduce need to pump ground water in Owens Valley.	Increase use of sprinklers; line ditches and canals in Owens Valley.
Colorado Desert	66	73	Increase present supply, optimize salt balance.	Line canals. Improve irrigation management.

APPENDIXES

A. Glossary of Terms
B. References

APPENDIX A

GLOSSARY OF TERMS

Acre-Foot. A measure of the volume (such as irrigation water) that would cover 1 acre to a depth of 1 foot. In the metric system, volume is expressed as cubic metres. One acre-foot equals 1,233.5 cubic metres.

afpcy. Acre-feet per capita per year. In the metric system, this water use rate is expressed as cubic metres per capita per year.

Applied Water. Water delivered to a user. Also called delivered water. Applied water may be used for either inside uses or for outside watering. It does not include precipitation or distribution losses. It may apply to metered or unmetered deliveries.

Brackish Water. Sea water or any mixture of sea water and surface runoff which occurs in estuaries or at the lower reaches of streams that discharge into a bay or ocean or other highly mineralized water.

Commercial Establishment. Establishments providing services, engaged in the fabrication of structures or other fixed improvement, or otherwise occupied in nonmanufacturing profit-motivated activities. Examples are retail stores, restaurants, entertainment facilities, and home building concerns.

Commercial Water Use. Water used by a commercial establishment.

Consumptive Use (Urban). Water transpired by urban-associated vegetative growth and used in building plant tissue; and water evaporated from soils, water surfaces, plant foliage, and impervious surfaces. It also includes water consumed inside homes, commercial establishments, and industrial establishments through evaporation in cooling, cleaning, and food preparation processes.

Crop Water Requirement. Crop evapotranspiration (ET) plus water required to maintain a favorable salt content or leaching requirement (LR) in the soil solution.

Delivered Water. See "Applied Water".

Domestic Water Use. See "Residential Water Use".

Establishment. An economic unit which produces goods or services, such as a farm, a mine, a factory, or a store. In most instances, the establishment is at a single physical location, and is engaged in only one, or predominantly one, type of economic activity.

ET. — Evapotranspiration.

ETAW. Evapotranspiration of applied water.

Evaporative Demand. The collective influence of all climatic factors on the rate of evaporation of water.

Evapotranspiration (ET). The quantity of water transpired by plants; retained in plant tissue; and evaporated from plant foliage, from surrounding surfaces, and from adjacent soil, in a specified time period. Usually expressed in depth of water per unit area. As used in this report, evapotranspiration refers to outside consumptive use.

External Water Use. See "Outside Water Use".

Farm Ditch Efficiency. The percent of the total volume of water supplied to the farm which is applied to the fields.

Farm Irrigation Efficiency. The percent of total volume of water under the farmer's control which is actually used in evapotranspiration (ET) plus that required to maintain a favorable salt content or leaching requirement (LR) in the soil solution.

Fertility Rate. The average number of children a woman will have during her childbearing years.

Flat Rate Water. Water sold to customers at a fixed rate irrespective of quantity used.

gpcd. Gallons per capita per day. In the metric system this rate is expressed as litres per capita per day.

HSA. Hydrologic study area.

Industrial Establishment. An establishment engaged in the mechanical or chemical transformation of inorganic or organic substances into new products, and usually described as plants, factories, or mills, which characteristically use power-driven machines and materials-handling equipment. Establishments engaged in assembling component parts of manufactured products are also considered manufacturing if the new product is neither a structure nor other fixed improvement.

Industrial Water Use. Water used by an industrial establishment.

Inside Water Use. That part of the water delivery used within a home, commercial establishment, or manufacturing establishment for any purpose; also called "Internal Water Use".

Internal Water Use. See "Inside Water Use".

Irrecoverable Water. That portion of delivered water degraded physically or chemically to a level that makes it uneconomical to reclaim, and water discharged directly to the ocean or other land or water body where the water is no longer recoverable.

Leaching Requirement (LR). The water that must pass through the root zone in order to prevent soil salinity from reaching a specific level.

Manufacturing Establishment. See "Industrial Establishment".

Metered Water. Water sold to customers on the basis of actual measured use; does not include losses in distribution.

Municipal and Industrial Water Use (M&I). See "Urban Water Use" and also "Water Produced".

Net Water Use (Urban). The sum of delivered water consumptively used and irrecoverably lost.

Outside Water Use. The use of water for irrigation of gardens, lawns, and ornamental shrubs, and for replenishing swimming pools, car washing, etc.; also called "External Water Use".

Precipitation. The total measurable supply of water of all forms of falling moisture, including dew, rain, mist, snow, hail, and sleet; usually expressed as depth of liquid water on a horizontal surface on a daily, monthly, or yearly basis.

Private, Industry-Produced Water. Privately pumped or diverted water used by industries; may include fresh or brackish water.

Privately-Produced Water. Water pumped or diverted by an individual or company for self use; excludes agency-produced water.

Public Facilities. All structures, parks, and public places, other than recreational areas, engaged either in serving the public or in providing a public use.

Public Water Use. Water use associated with public facilities.

Reservoir Storage Efficiency. The percentage of the volume of water delivered from the reservoir for irrigation to the volume of water delivered to the storage reservoir for irrigation.

Residential Water Use. All inside and outside uses of water associated with residential areas.

Service Area. The area of land included in the distribution system of an agency.

Sewage. In this report, waste water from sewage treatment facilities; does not include storm and surface water.

Type of Water Use. A distinction of water use based on either a kind of land use (recreational, residential, commercial, etc.) or on a kind of water use (outside use, personal use, swimming pool use, dishwashing use, etc.).

Unaccountable Water. The difference between the quantity of water introduced into the system and the quantity delivered to the eventual consumer; usually expressed as a percentage of delivered water. Many local factors affect this percentage from system to system.

Unit Water Use (Unit Value of Water Use). The average quantity of water used per person, acre, etc., over a specified period of time.

Urban Per-Capita Water Use. A unit value of water use which encompasses all urban uses of water in a service area.

Urban Water Use. The use of water for urban purposes, including residential, commercial, industrial, recreational, military, and institutional classes. The term is applied in the sense that it is a kind of use rather than a place of use. Includes delivered water and unaccountable water. See also "Water Produced".

Water Agency. An agency organized, founded, or established to produce and distribute water directly or indirectly to customers; the two major types are privately-owned companies and publicly-owned companies. Private companies consist of commercial companies and mutual water groups; public companies consist of water districts and municipally-owned water departments.

Water Application Efficiency. The percentage of the volume of water used in ET plus LR for a specified irrigated area (field or fields) to the total volume applied to that area.

Water Conveyance Efficiency. The percentage of the volume of water delivered to the farm or farms by a conveyance system to the volume of water delivered to the conveyance system at the supply source.

Water Produced. The total water into the system or the sum of applied water and unaccountable water; also called "Urban Water Use".

APPENDIX B
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